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Assessment of Nuclear Medicine Capabilities in Responding to a Radiological Terrorism Event

Robert Z. Stodilka and Diana Wilkinson

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Assessment of Nuclear Medicine Capabilities in Responding to a Radiological Terrorism Event

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Abstract

Substantial effort has been placed into enhancing federal capabilities for responding to a Chemical, Biological, Radiological, or Nuclear (CBRN) terrorist attack. However, little emphasis has been placed on including the local-level medical responders in these efforts. In effecting response to a radiological incident, potentially useful resources to access are health care professionals with training in matters of ionizing radiation, namely: nuclear medicine physicians, radiologists, radiation oncologists, medical physicists, and technologists. In this report, we focus on Nuclear Medicine expertise in Canada, and place this expertise into the context of assisting with a radiological terrorist incident. Nuclear Medicine expertise, along with its supporting infrastructure has already been deployed in proportion to the distribution of the civilian population. Given the expectations that the civilian population places in these health care professionals, their immediate access to specialized equipment, and the delay between a radiological terrorist incident and the arrival of federal expert capabilities, it is likely that these health care professionals will play important roles in emergency response. These roles will likely be: identifying the nature of the incident, triage, decontamination, coordinating with First Responders, and communicating with the media. Acknowledging the potential value of these professionals in responding to a radiological terrorist incident, steps should be taken to enlist their support and integrate them into a coherent national strategy.

Résumé

Des efforts importants ont été mis en place afin d'accroître les capacités fédérales d'intervention à une attaque terroriste de nature chimique, biologique, radiologique ou nucléaire (CBRN). Cependant, peu d'emphase a été mis sur l'intégration des intervenants médicaux régionaux. Les ressources potentielles qui pourraient intervenir suite à un incident radiologique sont les professionnels de la santé avec une formation en rayonnement ionisant, à savoir les spécialistes en médecine nucléaire, les radiologistes, les radio-oncologues, les physiciens médicaux et les technologues. Ce rapport se concentre sur l'expertise en médecine nucléaire au Canada et son soutien potentiel suite à un incident terroriste de nature radiologique. L'expertise en médecine nucléaire, ainsi que l'infrastructure qui s'y rapporte, a déjà été déployée en proportion avec la population civile. Etant donné les attentes de la population civile envers les professionnels de la santé, ainsi que l'accès immédiat à de l'équipement spécialisé, et le délai entre un incident terroriste de nature radiologique et l'arrivée des experts fédéraux, il est probable que ces professionnels de la santé joueront, de façon volontaire ou non, un rôle important suite à un tel incident. Leurs rôles probables seront l'identification de la nature de l'incident, le triage, la décontamination, la coordination avec les premiers intervenants et la communication avec les médias. En reconnaissant la valeur potentielle de ces professionnels à réagir à un incident terroriste de nature radiologique, des mesures devraient être mises en place afin d'assurer leur concours et de les intégrer à une stratégie nationale cohérente.

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Executive summary

Assessment of Nuclear Medicine Capabilities in Responding to a Radiological Terrorism Event

Robert Z Stodilka, Diana Wilkinson; DRDC Ottawa TM 2006-237; Defence R&D Canada – Ottawa; September 2006.

Introduction or background

In February 2002, DRDC Ottawa and Health Canada hosted two inter-departmental workshops on Radiological Counter-terrorism, designed to review Canada's federal capabilities. Arising from these workshops was the realization that Canada has a large untapped resource: the community of Nuclear Medicine professionals (Physicians, Physicists, Technologists) that – given their training and day-to-day experience – could meaningfully respond to medical issues (urgent and otherwise) arising from a radiological terrorism event.

Results

This report assesses the capabilities of the Nuclear Medicine community in responding to a radiological terrorism event. In particular, we describe current expertise, the capabilities of equipment (imaging, surveillance), and provide recommendations on how these resources might be accessed and coordinated during a crisis.

Significance

Nuclear Medicine expertise, along with its supporting infrastructure has already been deployed in proportion to the distribution of the civilian population. Given the trust that the civilian population places in these health care professionals, their immediate access to specialized equipment, and the delay between a radiological terrorist incident and the arrival of federal expert capabilities, it is likely that these health care professionals will play important roles - willingly or otherwise - in response. Thus, it would be of value to establish formal points-of-contact within this community, develop educational materials for them regarding incident response, and – ultimately – enlist their support.

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Sommaire

Assessment of Nuclear Medicine Capabilities in Responding to a Radiological Terrorism Event

Robert Stodilka, Diana Wilkinson ; DRDC Ottawa TM 2006-237; R & D pour la défense Canada – Ottawa; Septembre 2006.

Introduction ou contexte

En février 2002, RDDC Ottawa et Santé Canada ont organisé deux ateliers interministériels sur le contre-terrorisme radiologique afin de réviser les capacités fédérales. Ces ateliers ont mené à la conclusion qu'il existait au Canada une ressource inexploitée, soit les spécialistes en médecine nucléaire (médecins, physiciens, technologues) qui, grâce à leur formation et leur expérience quotidienne, pourraient contribuer de façon importante aux questions médicales (urgentes ou autres) suite à un incident terroriste de nature radiologique.

Résultats

Ce rapport évalue les capacités des entervenants en médecine nucléaire à répondre à un incident terroriste de nature radiologique. Ce rapport décrit l'expertise actuelle, les capacités de l'équipement disponible (imagerie, surveillance), et suggère quelles ressources pourraient être utilisées et coordonnées durant une crise.

Importance

L'expertise existante en médecine nucléaire ainsi que l'infrastructure qui s'y rattache a déjà été déployée en proportion avec la population civile. Etant donné la confiance que la population civile porte aux professionnels de la santé, à leur accès immédiat à de l'équipement spécialisé, et le délai entre un incident terroriste de nature radiologique et l'arrivée des experts fédéraux, il est probable que ces professionnels de la santé joueront, de gré ou de force, un rôle important suite à un tel incident. Il serait donc avantageux d'établir des points de contact officiels avec cette communauté, de développer du matériel didactique à leur intention et, en dernier ressort, d'assurer leur concours.

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1. Introduction

In recent years, substantial effort has been placed into enhancing federal capabilities for responding to a Chemical, Biological, Radiological, or Nuclear (CBRN) terrorist attack. These efforts include the development of terrorist scenarios, analyses of security gaps, and acquisition of detection / response capabilities such as the procurement of equipment and the creation of expert teams. Many of these initiatives are supported through the federal CBRN Research and Technology Initiative (CRTI). However, little emphasis has been placed on including in these efforts the local-level medical responders (First Responders). This is particularly true for hospitals, where patients will ultimately be delivered for care. These First Responders will be the first to react to a terrorist incident and they need to be prepared for such events.

In the event of a CBRN terrorist incident, the best defence in reducing casualties will be the ability of community leaders to mount an appropriate response [Franz *et al* 1997, Tucker 1997, Waeckerie 1991, Waeckerie *et al* 2001]. For example, local hospitals will be called upon to provide the care necessary to treat injuries and reduce deaths [Smith *et al* 2005, Waeckerie *et al* 1991]. In crisis situations, hospital staff have the required training to manage the significant numbers of casualties arising from both the incident proper, as well as the ensuing chaos and stress. However, much of this training is derived from expectations of natural disasters and conventional injuries such as earthquakes and motor vehicle accidents; while knowledge of effective response to CBRN terrorism, particularly RN, is lacking. Awareness of dealing with injuries and contamination resulting from terrorist events is generally considered to be low within the First Responder community. For example, Lazzilotti *et al* [2002] reported on a recent survey of physicians and nurses to determine their commitment to treat victims of a natural disaster versus a CBRN event. Their results ranked as follows, in order of most- to least-likely to help: natural disasters, explosion incidents, chemical incidents, biological incidents, contagious epidemics, and radiological events. Some First Responders have received Hazardous Materials (HAZMAT) training, which includes CBRN response; but their tasks end at the Emergency Department of the nearest hospital. It therefore becomes important to determine what resources can be used to mitigate this reluctance on the part of hospital-based health care providers, to deal with ionizing radiation while delivering uninterrupted care, both in the short-term by expertise and equipment already deployed, and long-term by increased educational efforts and improved medical intervention strategies.

In effecting response to a radiological incident, a potentially useful resource to access are health care professionals with training in matters of ionizing radiation; namely: nuclear medicine physicians, radiologists, radiation oncologists, medical physicists, and technologists [Mettler 2005, Pellmar and Rockwell 2005]; medical professionals generally not considered to be integral with the First Receiver community. These resources are represented within five professional organizations: the Canadian Association of Nuclear Medicine (CANM), representing about 400 nuclear medicine physicians; the Canadian Association of Medical Radiation Technologists (CAMRT), representing about 10,000 technologists; the Canadian College of Physicists in Medicine (CCPM) with 230 medical physicist, which is a component of the Canadian Organization of Medical Physicists (COMP) with 508 members; and the Canadian Association of Radiopharmaceuticals Sciences (CARS), representing about 120 radiopharmacists and radiochemists. In 1998, the Canadian Society of Nuclear Medicine (CSNM) was formed as a multidisciplinary professional Canadian organization with a common interest in the scientific and

clinical use of radionuclides. The CSNM, acting as an umbrella organization, holds annual scientific and business meetings; ensures communication among nuclear medicine professionals by publication of a newsletter and maintenance of a web site; and represents the opinions of the nuclear medicine community to federal regulatory agencies and industry. These organizations would each serve as useful entry points for establishing collaborations with the federal departments for enhancing Canadian RN medical emergency response network. Contact information for these professional organizations is listed in Annex B.

This report focuses on Nuclear Medicine expertise in Canada, and places this expertise into the context of assisting with a radiological terrorist incident. Nuclear medicine expertise, along with its supporting infrastructure has already been deployed in proportion to the distribution of the civilian population and is well positioned to assist in RN medical casualty management. These health care professionals will play important roles in emergency response. These roles will likely be: identifying the nature of the incident, triage, decontamination, coordinating with First Responders, consulting on treatment strategies and communicating with the media. Acknowledging the potential value of these professionals in responding to a radiological terrorist incident, steps should be taken to enlist their support and integrate them into a coherent national strategy.

2. Nuclear Medicine Expertise

2.1 Introduction

Nuclear medicine departments are licensed under the Nuclear Safety and Control Act [CNSC 1997] to carry on the practice of Diagnostic Nuclear Medicine, and in some larger hospitals conduct Therapeutic Nuclear Medicine and Human Research studies. These licences often include the possession and operation of radiation emitting devices. In larger centers, licenses typically provide for the issuance of internal permits to different laboratories carrying on biomedical research. The licenses include the designation of Nuclear Energy Workers who are typically: all Nuclear Medicine Technologists, Electrocardiogram Technicians, Veterinary Technicians, and some Nuclear Medicine Physicians. Nuclear Medicine Physicists are typically not Nuclear Energy Workers. It is also important to note that hospital staff (including all physicians, nurses, residents, dieticians and housekeeping) receive radiation safety training, however they are not Nuclear Energy Workers and do not have Nuclear Medicine Expertise. Their training and practical application of that training will be discussed in chapter 3.

2.2 Nuclear Medicine Physicians

Nuclear Medicine physicians are trained to administer radioisotopes to patients for the purposes of diagnosis and treatment, and interpret measurements of the distribution of those radioisotopes in the body. The practice of Nuclear Medicine is regulated in Canada by the College of Physicians and Surgeons of Canada. Nuclear Medicine physicians are also members of the Canadian Association of Nuclear Medicine.

The responsibilities of the Nuclear Medicine physician includes explaining to patients the risks and benefits associated with Nuclear Medicine procedures and ionizing radiation in general, administering radiopharmaceuticals for diagnostic purposes (a responsibility shared with technologists), administering therapeutic doses of radiopharmaceuticals, supervising cardiac stress tests, and interpreting the results of diagnostic tests (which includes reading scans and blood test results). In many smaller departments, the physician is also the radiation safety officer (RSO), although the day-to-day RSO duties are delegated to a technologist.

During their training, Nuclear Medicine physicians are taught how to use radiation detection equipment, conduct surveys, and interpret and implement various aspects of a radiation safety program. However, few of these skills are routinely practiced – especially since many responsibilities are delegated away. Nuclear Medicine physicians do not receive training during their residency on RN emergency response. Some Nuclear Medicine professional organizations – such as the (US-based) Society of Nuclear Medicine, have put efforts into counter-terrorism and emergency response education through public seminars and journal articles. However, there is no formal mechanism for ensuring information dissemination, thus awareness is sporadic at best. It would be useful to develop educational materials that can be easily deployed and accessed as a component of the continuing education program. Moreover, deployable casualty management tools, such as DRDC's portable reference tool designed to aid in radioisotope decorporation [Waller and Wilkinson 2006] would be very useful in the event of a radiological emergency.

2.3 Nuclear Medicine Technologists

Nuclear Medicine technologists represent the largest populations of radiation safety experts in Canada who have specialized training in patient management. The practice of Nuclear Medicine Technology is a health profession regulated in Canada by the Canadian Association of Medical Radiation Technologists (CAMRT).

The responsibilities of the Nuclear Medicine technologist include the preparation, calibration, and administration of radiopharmaceuticals and pharmaceuticals, under the supervision of a Nuclear Medicine physician; the operation of a variety of equipment including gamma cameras (and associated computers), bone mineral densitometry scanners, thyroid probes, well counters, dose calibrators, and portable survey equipment. They also perform laboratory procedures, such as the elution of radionuclide generators, the preparation of radiopharmaceuticals in fume hoods, and separation of cell fractions in blood samples. Nuclear Medicine technologists perform day-to-day quality control procedures in the Nuclear Medicine department, both for imaging and non-imaging equipment, and apply standards of radiation safety and protection. In some situations, Nuclear Medicine technologists order radiopharmaceuticals, and assist with the decommissioning of rooms. Their responsibilities can also include reporting to regulatory agencies on issues of radiation safety. These tasks are all done in the context of providing empathic patient care.

Nuclear Medicine technology training programs include both didactic and clinical training. Didactic course work includes: mathematics, chemistry, physics, computer science, radiation protection, anatomy, physiology, pathophysiology, and medical ethics. This training is augmented with clinical rotations in Nuclear Medicine departments, which allow for direct patient contact. Like Nuclear Medicine physicians, Nuclear Medicine technologists must also commit to obtaining annual continuing education hours to maintain accreditation with their profession college.

Due to their numbers, geographic distribution in Canada, and expertise in radiation health sciences, nuclear medicine technologists represent one of the most important, abundant, and rapidly-deployable assets in responding to a radiological terrorism incident. Within a hospital, their roles would include participating in the screening of individuals, decontamination, and radiation protection management. Beyond a hospital, their expertise allows them to use (or rapidly learn how to use) most existing portable radiation detection equipment (including spectrometry), conduct rapid surveys, and provide expert assistance to First Response crews in various aspects of radiation safety. Further, it is anticipated that the psychological response to a radiological terrorism incident will be overwhelming to both the general public and the Firs Responders. Thus, the early-on interaction of victims with a large cohort of empathic, highly trained radiation protection and patient management caregivers may substantially reduce early and latent trauma and debilitation within the community.

2.4 Nuclear Medicine Physicists

The responsibilities of the Nuclear Medicine physicist include: selection of instrumentation and coordination of installation, which can include site planning and obtaining regulatory approvals; acceptance testing and routine quality control procedures of equipment; and dosimetry for therapy

and diagnostic procedures. In larger facilities, Nuclear Medicine physicists also provide assistance with licensing activities and computer processing. They are commonly employed in larger hospital facilities that are affiliated with a university, where they have research and teaching responsibilities. Most Nuclear Medicine physicists in Canada have research programs investigating improved imaging instrumentation, novel uses of radiopharmaceuticals, or investigating disease mechanisms either in animal models or clinical trials in human subjects.

Physicists usually have doctorate degrees, although there is no pre-defined and regulated educational program. Their practice is governed by the Canadian College of Physicists in Medicine (CCPM), which provides assurance to nuclear medicine departments regarding their competence. To attain membership in the CCPM, the physicist must pass an examination testing knowledge of medical physics, including the following aspects of radiation protection: Radiation protection fundamentals such as simple shielding calculations, dominant photon interaction mechanism in tissue at different photon energies; dosimetric quantities and units; natural and human-made sources of radiation exposure; biological effects of ionizing radiation; instrumentation; basic external dosimetry; and basic internal dosimetry; As Low As Reasonably Achievable (ALARA) principles and shielding; counting statistics; monitoring and interpretation; transportation and waste management; emergencies and incident preparation/planning and response; non-ionizing radiation; organization and administration of radiation safety programs (licensing, relationships to hospital administration/occupational health & safety); and nuclear safety regulations.

Physicists possess a more detailed understanding of radiation protection than either physicians or technologists. However because they are in short supply, they could provide little manpower in responding to a radiological terrorism event. Their expertise may be best utilized in preparing for a radiological terrorist event; that is, identifying what instrumentation would most benefit a response, developing procedures for patient screening, decontamination and flow through a busy emergency department, developing rapid procedures for dose estimates, and developing and providing education materials to improve awareness for the need for terrorism countermeasures.

3. Radiation Protection Expertise

3.1 Introduction

All workers who are required to enter restricted areas must first undergo radiation safety training to ensure they are familiar with safe practices, standard operating procedures of that area, and regulatory requirements. The workers must complete their training before assuming their duties, and must undergo regular re-training thereafter. The level of training is commensurate with the workers' responsibilities, authority, and the magnitude of the risk of their activities; however, it is not at the level of Nuclear Medicine expertise. Trained workers include physicians (other than nuclear medicine physicians discussed above), technologists, nurses who provide care for patients (mostly radioiodine therapy patients), electrocardiogram technicians, and other staff who routinely enter restricted areas. Other staff includes housekeeping and maintenance personnel who clean nuclear medicine departments or work in areas where radioiodine therapy patients reside; and security personnel, whose rounds include inspection of nuclear medicine departments. Additionally, in some larger hospitals, all nurses receive some basic level of radiation protection training since they can encounter patients who have been administered radiopharmaceuticals for diagnostic purposes. The training to these individuals is usually provided by the Radiation Safety Officers (RSOs). All staff that is working with the Nuclear Medicine patients must be issued personnel dosimeters.

3.2 Radiation Safety Officers

According to Canadian Nuclear Safety Commission (CNSC) Regulations, all facilities performing nuclear medicine must designate a Radiation Safety Officer (RSO). In a smaller facility, the RSO may be a Nuclear Medicine physician, who handles regulatory issues part-time and assigns surveys and quality control tasks to a technologist. A hospital with a larger nuclear medicine program, however, will likely employ a full-time RSO who holds a Master's or a Doctoral degree in a relevant specialty, and is certified by CCPM or CAMRT. In very large multi-site programs that incorporate research and teaching, the RSO may be assisted by medical physicists, technicians, and clerical personnel. The duties of the RSO[1] include licensing activities, such as communicating with the regulatory authorities, and managing internal permits; writing procedures; arranging for certification and re-certification of equipment; providing training; monitoring personal dosimeters; conducting periodic surveys; representing the department during inspections and audits; investigating incidents; and directing actions during emergencies such as spills and personnel contamination.

Similar to a Nuclear Medicine physicist, the RSO has increased knowledge and awareness of radiation protection. Their best value in responding to a radiological terrorism incident is likely placed in improving preparedness beforehand. Working with a Nuclear Medicine physicist, the RSO could aid in the selection of appropriate surveillance equipment, and develop in-house procedures for preparing for the arrival of casualties. Given their day-to-day responsibilities and direct line of communication with regulatory authorities, RSOs are likely the best candidates for

[1] Described in detail in Annex D.

developing improved security measures for safeguarding nuclear materials stored within their hospital.

Although the therapy will be overseen by the department of nuclear medicine, the day-to-day care for the patients will be administered by staff who may not be a part of that department. In particular, nurses usually spend the most time caring for the patient. Thus, the staff (including physicians, nurses, residents, dieticians, and housekeeping – on all shifts) on the ward where the patient is housed must all be trained, and regularly re-trained, in radiation protection practices. Housekeeping staff must also undergo a limited amount of training, and be instructed not to enter the patient’s room, nor remove anything from that room. Staff should be reminded using written instructions placed on the patient’s chart. All staff who will be working with the patient must be issued personnel dosimeters.

4. Nuclear Medicine Tools

4.1 Introduction

Both expertise and equipment will be called upon in responding to a radiological terrorism incident. First Responders are equipped with portable radiation detection equipment, and some government bodies have acquired portal monitors for whole-body screening, and field-deployable spectrometers. However, once patients have been delivered to hospitals, or a large number present themselves at the emergency department doors (‘walk-in cases’), it will likely fall on hospitals resources to manage their care. This care may include a variety of procedures such as a simple pass/fail whole body surveys (and determining appropriate criteria for pass/fail during a crisis) and/or complex procedures such as monitoring the efficacy of radionuclide decorporation in critical organs. To assess the capabilities of hospitals in meeting these requirements, and identify gaps in capabilities that must be filled, we provide a description of radiation detection instrumentation typically found in a Nuclear Medicine department. In the practice of Nuclear Medicine, a variety of instrumentation is used to detect and measure radiation and radioactive materials, and quantitatively image their distribution. These instruments are highly sensitive, calibrated regularly to medical standards, and used on a daily basis. It is not within the scope of this report to elaborate on the specifics of the tools used, but rather describe the extent of Nuclear Medicine department capabilities and expertise in being able to use these instruments.

4.2 Portable detection instruments

In the context of responding to a radiological terrorism incident, the hospital’s portable detection instruments would likely be deployed to the emergency department and used there by a Nuclear Medicine technologist to screen incoming casualties, and/or monitor decontamination efforts within that department.

Figure 1: Portable Detection Instrument

Due to their limited numbers, it is unlikely they would become available to First Responders to use outside of the hospital. There is a range of these portable instruments that can be found at different hospitals and the availability is highly dependent on the hospital size and RN associated functions. The actual number and types available should be determined through a cross-country survey of RN associated capabilities and resources.

Most hospitals would probably not have portable spectrometry equipment, however; it may be possible in some hospitals to conduct radionuclide analysis and identification using equipment within the Nuclear Medicine department.

4.3 Dose Calibrator

In a Nuclear Medicine department, the dose calibrator is the most often used instrument for measuring quantities of radioactivity, either for measuring elutions from radionuclide generators or radiopharmaceuticals prior to injection.

Dose calibrators undergo quality control evaluation on a regular basis, as required by the CNSC. The required tests are presented in the following table. In all cases, if any test fails, the dose calibrator must be repaired, or a new one purchased.

Test	Frequency	Description
Constancy	Daily	Performed, each morning, by measuring a long-lived radioactive source (^{137}Cs) in the dose calibrator. Daily variation is observed, and must not exceed ±10% relative to the preceding constancy check.
Linearity	Acceptance testing; Quarterly; After recalibration or repair	(Shield method) The dose calibrator must demonstrate the ability to measure activity accurately over a large range of activities. This test is performed by measuring a short-lived radioactive source (^{99m}Tc) at different times, plotting measured activity as a function of time, and fitting the results to an exponential function. The test begins with the highest activity used in clinical procedures, and ends when that source decays to less than 1 MBq. The test fails if any point deviates from the fit curve in excess of ±10%.
Accuracy	Acceptance testing; Quarterly; After recalibration or repair	Accuracy is evaluated by measuring the activity of two long-lived radionuclides (^{57}Co and ^{137}Cs) with known activities in the dose calibrator and comparing the measured activity with their true activities. The sources are certified by a calibration or standards body, such as the National Institute of Standards and Technology (NIST). The measured value should not differ from the true value by more than ±10%.

Geometry	Acceptance testing; After recalibration or repair	Variations in geometric configuration of the container will influence measurement accuracy. For example, 1 MBq in a 1 mL or 30 mL volume will return different values in a dose calibrator. Similarly, the measured value can depend on the type of container (plastic or glass). Correction factors must be determined for these geometric variations and applied to the measured activities, if the error exceeds ±10%.

Figure 2: Capintec Dose Calibrator

In the context of a radiological terrorist incident response, one possible use of the dose calibrator lies in its ability to quickly (<30 s) quantify the amount of radioactivity in samples smaller than approximately 100 mL. Potentially, this capability would have value in rapidly screening substantial quantities of shrapnel, as might be found embedded in victims of dirty bombs [Smith *et al* 2005].

4.4 Thyroid Probes

Thyroid uptake is defined as the fraction of an administered amount of radioiodine (^{131}I or ^{123}I) that accumulates in the thyroid at some specified time post administration. Thyroid Probes are used to measure thyroid uptake. Thyroid uptake is useful in: determining the amount of radioiodine to be administered to patients for therapy of hyperthyroidism due to Graves' disease or toxic nodular goitre, differentiating subacute or painless thyroiditis from Graves' disease and other forms of hyperthyroidism, and assisting in the diagnosis of hyperthyroidism. Thyroid uptake can also be measured using a gamma camera (described in 3.6).

The efficiency of the thyroid probe varies inversely with the square of the distance between the detector and the thyroid. The efficiency is also reduced by attenuation of γ-rays either in the

thyroid or surrounding tissue[2]. This effect is corrected by calibrating the thyroid probe using a phantom that is approximately the same size and density as the patient's neck. Some γ-rays also undergo Compton scattering in the thyroid or surrounding tissue, and may reach the detector. These scattered γ-rays are rejected from the counting process by an energy window setting on the pulse height analyzer.

The first step in the thyroid uptake test is to place the radioiodine capsule (that will later be administered to the patient) into a Lucite neck phantom, place the phantom at a fixed distance from the thyroid probe, and record the counts over a specified period of time. The number of recorded counts is considered the Standard Count. The capsule is then administered to the patient orally, and the Thyroid Count is obtained at the same distance as the Standard Count (that is, in the same geometry). Thyroid uptake is usually measured at a distance of 25 to 30 cm between the face of the crystal and the anterior neck. The measurement of thyroid uptake is usually performed 24 hours post administration of the radioiodine, although in some situations, the measurement may be performed 2 to 6 hours post radioiodine administration. The room Background Count is taken and subtracted from the Standard Count, and the lower Thigh Count is taken as background to be subtracted from the Thyroid Count. The Radioiodine uptake (RAIU) is then calculated as follows:

$$\text{RAIU} = \frac{\text{Neck Counts [cpm]} - \text{Thigh Counts [cpm]}}{\text{Standard Counts [cpm]} - \text{Background Counts [cpm]}} \times 100\%$$

Figure 3: Subject positioned for thyroid counting using thyroid probe

The concern from radioiodine contamination, as a consequence of an RN event, and the need for providing potassium iodide as a treatment strategy is pervasive throughout the literature [Vastag

[2] This is an operational definition of γ-ray attenuation, which includes γ-rays that undergo Compton scatter away from the field-of-view, and are not detected.

2003]. The most established tool for quantifying radioiodine uptake is the thyroid probe. The value of the thyroid probe in responding to a radiological terrorist incident lies in its ability to screen large numbers of casualties in a simple way with good intra- and inter-user reproducibility. Moreover, the operation of the probe requires only one individual, therefore placing little burden on personnel resources. For casualties with contaminated thyroids, the probe would allow for those people to be repeatedly and quantitatively assessed throughout the course of medical intervention.

4.5 Well Counters

Well counter is a major Nuclear Medicine department instrument used primarily for radioimmunoassay, detection of radioactivity blood and urine samples, and preparation and quality control of radiopharmaceuticals. NaI(Tl) well counters are useful in counting x- or γ-ray emitting radionuclides. β emitting radionuclides can be counted but the efficacy is reduced due to dependency on counting bremsstrahlung productions.

In the aftermath of a radiological terrorist incident, the well counter would likely take on two roles: (1) screening blood, tissue and clothing samples for contamination; and (2) screening wipe tests from surveys in efforts to control contamination. The automation of well counters makes them particularly convenient to screening hundreds of samples with little or no user intervention, and results would be available by the next day.

Figure 4: Well Counter

Although speculative, one application of this technology may lie in monitoring large numbers of people for trace quantities (ie. below deleterious effects) of contamination. This may be useful in long-term monitoring of a population, or providing improved assurances for psychological casualties (assuming negative findings).

4.6 Gamma Cameras

The Gamma Camera[3] is a most commonly used imaging device in Nuclear Medicine. It consists of a large two-dimensional planar detector that is used to measure a two-dimensional projection of the activity inside a patient's body. Gamma Cameras also have spectroscopy capabilities, and can image multiple gamma-ray energies simultaneously, as is required for certain Nuclear Medicine procedures. The advantage of a Gamma Camera is that it is capable of recording both dynamic and static images of the area of interest in the patient.

The camera consists of a lead collimator, that is interchangeable for different applications; a sodium iodide crystal (NaI(Tl)); and an array of photomultiplier tubes and electronic circuits. A schematic diagram, photo, and sample projection are shown in Figure 5, and typical performance specifications are presented in the table below.

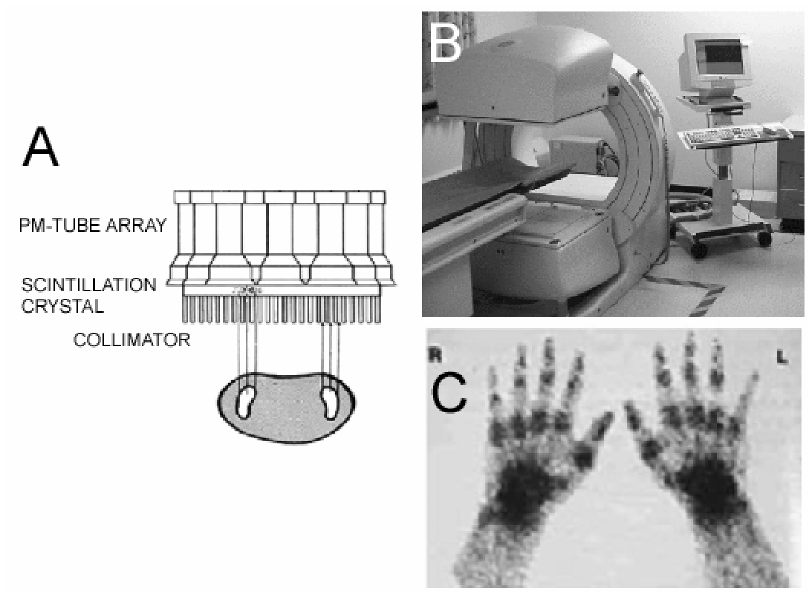

Figure 5: Gamma camera: (A) Schematic showing collimator, scintillation crystal and photomultiplier tube array; (B) General Electric double-head gamma camera; (C) Gamma camera projection scan of hands.

[3] Sometimes called the Anger Camera after its inventor, Hal Anger or Scintillation Camera

Name	LEHR[4]	LEGP	MEGP	HEGP
Application	Bone studies	General	^{111}In and ^{67}Ga studies	^{131}I studies
Field-of-View [mm]	540×400	540×400	540×400	540×400
% Penetration at 140 keV	0.3	0.8	2.0	2.0
Sensitivity [cpm/mCi @ 10 cm] 3/8” [5], 1”	160 , 171	270 , 290	144 , 163	97 , 160
Resolution FWHM [mm] at 10 cm 3/8” , 1”	7.4 , 8.1	9.0 , 9.8	9.4 , 11.5	12.0 , 13.0
Hole diameter [mm]	1.5	1.9	3.0	4.0
Septal thickness [mm]	0.2	0.2	1.05	1.8
Hole length [mm]	35	35	58	66
Weight [kg]	60	50	103	131

Performance Specifications of a typical family of collimators[6]

The Gamma Camera can also be used for tomography. The projected images can then be used to compute the original spatial distribution of the radionuclide within a slice or a volume; this procedure, also used in X-ray computed tomography (X-ray CT) is termed tomographic reconstruction, and is based on the mathematics of the Radon transform. A Gamma Camera with tomographic capabilities is said to be capable of Single Photon Emission Computed Tomography (SPECT). SPECT capabilities are available in almost all nuclear medicine departments. Recently, a SPECT / X-ray CT Hybrid Systems have become available, and are being installed in many hospitals. Superposition of SPECT scans onto X-ray CT scans allows internalized contamination to be localized precisely in three dimensions by showing relative position to underlying anatomy. A sample Hybrid SPECT/CT image is shown in Figure 6.

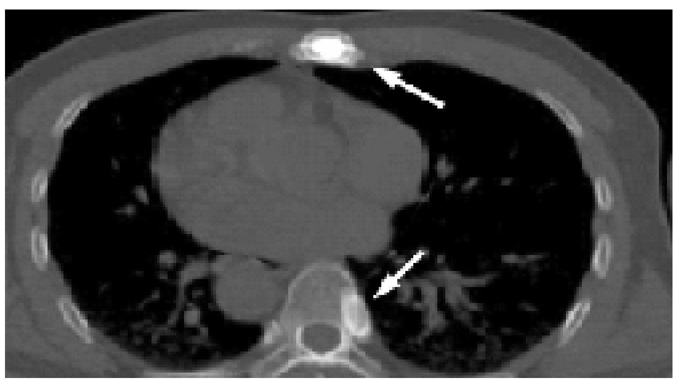

Figure 6: SPECT/CT Hybrid image of mid-thorax. Radiopharmaceutical distribution (shown by arrows) is superimposed onto underlying anatomical features, allowing precise three-dimensional localization.

In the context of radiological counter-terrorism, the significance of the Gamma Camera is that it is among the largest detectors of gamma radiation in Canada. Typically crystals are over 50 cm × 40 cm in size, and can be as thick as one-half inch, and there are hundreds of them in Canada. The majority of them have spectroscopy and tomographic capabilities, allowing them to localize,

[4] LEHR = Low Energy High Resolution , LEGP = Low Energy General Purpose , MEGP = Medium Energy General Purpose , HEGP = High Energy General Purpose

[5] Thickness of NaI(Tl) crystal, measured in inches. Thicker crystals have improved sensitivity, but reduced resolution.

[6] Specifications for General Electric Infinia collimator family

three-dimensionally, the distribution of multiple gamma-emitting radionuclides inside the body. This capability would be valuable in diagnosing internal contamination, or monitoring the efficacy of a decorporation treatment regimen. The devices provide for a reasonable throughput: typical scans times are approximately 30 minutes.

4.7 Radiopharmaceuticals[7]

A radiopharmaceutical consists of a non-radioactive chemical compound, with certain desirable biological properties, and a radioactive atom that can be detected by its emissions. The mechanism of localization of a radiopharmaceutical in a target organ can be as simple as the physical trapping of particles, or as complex as an antigen-antibody reaction. The ability to detect the radiopharmaceutical also allows its location and kinetic properties to be determined, which can be useful in diagnosing disease, monitoring therapy, or measuring functional properties of an organ (such as volume of blood flow through the heart). In order to provide clinically useful information, the pharmaceutical and radioactive atom must remain joined once inside the body. The binding of the pharmaceutical to the radioactive atom is termed 'compounding'.

Radionuclides used in nuclear medicine are produced from three sources: generators (which are the most common), medical cyclotrons (typically found in only large hospitals performing Positron Emission Tomography procedures), and nuclear reactors. The source of radionuclides determines its cost, accessibility, and how the radionuclide is regulated [CNSC 1997]. Generators are compact, and easily transported. Radionuclides produced by cyclotrons or reactors are processed in a central facility. If the half-life of these radionuclides is long enough (hours), they can be shipped to other radiopharmacies or hospitals throughout the country. Some examples include: ^{67}Ga, ^{111}In, ^{131}I, and ^{201}Tl. Many radiopharmaceuticals are compounded at the nuclear medicine departments in which they will be used. These laboratories take on the burden of pharmaceutical manufacturers and are required to perform quality control analysis of the radiopharmaceuticals produced. The amount of nuclear material present in a typical Nuclear Medicine facility depends on their activities and will vary with time.

The capability of the Nuclear Medicine departments to safely deal with radiopharmaceuticals on daily basis suggests that they would also have expertise in dealing with RN casualties that may have internal contamination. They would be a highly qualified and should be recruited, as advisors, early in the medical casualty management process.

Radionuclide	Half-life	Principle emissions[8]
^{32}P	14 days	β_{max}=1.7 , β_{mean}=0.695
^{51}Cr	27.7 days	γ=320 (9%)
^{57}Co	270 days	γ =14 (9%), 122 (86%), 136 (11%)
^{67}Ga	3.25 days	γ =93 (38%), 184 (24%), 300 (22%)

[7] The term "radiopharmaceutical" is a misnomer since it implies inducing a pharmacological reaction. Most radiopharmaceuticals are administered well below pharmacological concentrations: trace quantities (usually nanomolar to picomolar concentrations), and should more appropriately be called radio*tracers*.
[8] γ-ray energies in [keV], β particle energies in [MeV], Auger electron energies in [keV], numbers in parentheses is γ abundance per disintegration.

^{81m}Kr	13 seconds	γ =190 (67%)
^{89}Sr	50 dasys	β_{max} =1.46, β_{mean} =0.58
^{90}Y	2.7 days	β_{max} =2.3, β_{mean} =0.94
^{111}In	2.8 days	γ =171 (90%), 245 (94%), Auger=0.6, 2.4, 19.2, 25.4, 22.3
^{123}I	13.3 hours	γ =159 (83%)
^{125}I	60 days	γ =35 (7%)
^{131}I	8 days	γ =364 (82%), 637 (7%), 723 (2%), β_{max} =0.606, β_{mean} =0.19
^{133}Xe	5.3 days	γ =81 (37%)
^{153}Sm	1.9 days	γ=103 (28%), β_{max} =0.81 , β_{mean} =0.24
^{201}Tl	3.08 days	γ =69, 80 (95%), 135 (2.5%), 167 (10%)

Nuclear characteristics of non-^{99m}Tc single photon emitting radionuclides

4.8 Radionuclide Generators

Radionuclide generators are fundamental to the practice of nuclear medicine. They are easily transportable and provide a convenient source of clinically-useful, short-lived radionuclides, and are used by all nuclear medicine departments. A radionuclide generator has three fundamental requirements: (1) that the parent radionuclide has a longer half-life than the daughter radionuclide, (2) that the daughter is chemically distinct from the parent and can be separated easily from the parent, and (3) the daughter has nuclear properties that are useful clinically. The daughter radionuclide is then utilized in the preparation of radiopharmaceuticals.

Figure 7: Nuclear Medicine $^{99}Mo \rightarrow {}^{99m}Tc$ generator

Several radionuclide generators are typically found in nuclear medicine departments. These are:

^{99}Mo (66 hours) $\rightarrow$ ^{99m}Tc (6 hours)

^{113}Sn (117 days) $\rightarrow$ ^{113m}In (100 min)

$$^{68}\text{Ge (271 days)} \rightarrow {}^{68}\text{Ga (68 min)}$$

$$^{82}\text{Sr (25 days)} \rightarrow {}^{82}\text{Rb (75 sec)}$$

$$^{81}\text{Rb (4.6 hours)} \rightarrow {}^{81m}\text{Kr (13 sec).}$$

The most common radionuclide generator is the ^{99}Mo→^{99m}Tc generator. A busy nuclear medicine department will use one per week, each shipped with approximately 150 GBq of ^{99}Mo.

Many authors have speculated on what radionuclide(s) would likely be used in a radiological terrorist incident, recently summarized by Steinhausler [2005]: reactor-produced ^{241}Am, ^{252}Cf, ^{137}Cs, ^{60}Co, ^{192}Ir, ^{238}Pu, ^{90}Sr, natural radioactive nuclide ^{226}Ra, ^{103}Pd, and spent fuel; and some have suggested ^{131}I which is used in nuclear medicine [Sinzinger *et al* 2004, Carney *et al* 2003, Mettler 2005, Schneider *et al* 2002]. However, radiological terrorism is not expected to cause massive numbers of deaths or injuries from exposure to radiation. Rather, its effect is to complicate rescue efforts and recovery work, rendering the latter more expensive because of the presence of radiation hazards [Lubenau and Strom 2002, NCRP 2001]. Considering that radiological terrorism is also likely to cause widespread psychological trauma – regardless of the choice of radionuclide, the importance of acquiring one radionuclide over another may not be as important as whether the incident was radiological in nature, or chemical or biological. This brings us to the point of selecting a nuclear material based on accessibility, rather than radiological properties. Interestingly, we have not seen discussed the potential for using the ^{99}Mo→^{99m}Tc generator. Although beyond the scope of this manuscript, it is interesting to note that hundreds of these generators are transported across Canada every month, and in some cases arriving at their destinations outside of regular working hours [Lawson *et al* 2004], making them relatively easy to obtain. Fortunately, ^{99m}Tc, like other radionuclides used in nuclear medicine, is [9]easy to detect, and has a reasonably short half-life (unlike its parent).

4.9 Spill kits

Nuclear Medicine Departments are all equipped with spill kits, allowing for the clean-up of solid and liquid contamination, which can arise from a variety of incidents, including hotlab accidents and patient soiling. These spill kits usually contain the following items[9]:

Basic Spill Kit:

- Labels, pen, tape and cord to cordon off contaminated area
- Dust pan and brush, sponge, scrub brush and pail
- Supply of absorbent paper
- Disposable gloves, foot covers and aprons
- 2× One litre of one of: RadiacWash, Decon, Radoff, or Countoff, and a spray bottle
- Plastic bags for waste products

[9] St. Joseph's Hospital, London, Ontaio

- Copy of Radiation Safety Manual Chapter on “Radionuclide Laboratory Accident Procedures”

Advanced Spill Kit:

- Basic Spill Kit
- Disposable coveralls
- Respirator to reduce inhalation of aerosols and fumes
- One 40 litre or larger plastic drum
- Pair of tongs and a sponge mop
- 2× Four litres of one of: RadiacWash, Decon, Radoff, or Countoff, and a spray bottle

The spill kits are designed for the clean-up of small accidents, involving perhaps a single room and only a few people. As such, they would be inadequate for dealing with a disaster involving many people. However, these spill kits are inexpensive, and composed of readily available materials that can be procured quickly even during a crisis.

4.10 Medical Internal Radiation Dosimetry (MIRD)

MIRD data is readily available for many radiopharmaceuticals. During the aftermath of a radiological terrorist incident, MIRD can be used to estimate committed doses arising from internally deposited radionuclides. The pre-requisite information for employing MIRD would be: chemical form of contaminant (often not available early in the event) and current distribution within the body (which could be quantitatively measured for gamma-emitters using SPECT). However, employing MIRD for scenarios not common to nuclear medicine would require the expertise of a medical physicist.

MIRD is typically accessed through the MIRDOSE 3 software. This software was developed by the Oak Ridge Institute for Science and Education (Oak Ridge, TN). The software has phantom libraries which permit the calculation of doses for individuals of different age and size and for women at different stages of pregnancy. The software does not include libraries of doses for nuclear medicine radiopharmaceuticals; instead, the user must input data describing the biokinetics of the radiopharmaceutical. This information can be found in the literature. Kinetic models for different radiopharmaceuticals change often, as new information becomes available and as models change and improve. Unfortunately, MIRDOSE 3 is no longer available due to regulatory concerns expressed by the Food and Drug Administration. The successor to MIRDOSE 3 is OLINDA (published by Vanderbilt University and approved by the FDA).

Software programs are also available for dosimetry calculations based on activity measurements of excreted fluids and biokinetic models of specific radionuclides[10]; however, they are not typically found in Nuclear Medicine departments.

[10] See, for example, www.wise-uranium.org/rdr.html

5. Nuclear Medicine Operations

5.1 Clinical Care Settings, Populations

Nuclear Medicine in Canada is practised in three settings: stand-alone clinic, community hospital, and teaching/research hospital. Stand-alone clinics have limited instrumentation and staff – some may not even have a full-time Nuclear Medicine physician. Their patient populations usually require only 'simple and safe' diagnostic procedures. Their value in responding to a radiological terrorist incident would be negligible. At the opposite end of the spectrum is the teaching/research hospital. These hospitals are often affiliated with universities and have intensive research programs. Due to their larger size and connectivity with smaller regional hospitals, the teaching/research hospital will serve a large catchment area. The nuclear medicine department of such a hospital will have the ability to deal with complex and risky procedures, including imaging procedures involving neonates or patients requiring life-support. Many teaching/research hospitals will also have a Nuclear Medicine physicist on staff to provide assistance with instrumentation and dosimetry for unusual cases. These hospitals are likely to also be more familiar with radioiodine therapy procedures, requiring them to have designated treatment rooms and additional staff specially trained to deal with internal contamination. Because of their importance to their communities, many larger hospitals will also have disaster response plans in place. Some Nuclear Medicine departments have limited plans in place to deal with radiological disasters; however, it is unlikely that staff outside of Nuclear Medicine review these plans regularly.

5.2 Therapy Patients

The procedures that utilize the greatest amounts of radioactive material and require the most effort in terms of monitoring and contamination control are procedures for administering therapy using unsealed internalized sources. Therapy can be administered for curative or palliative care, generally for the treatment of thyroid disorders or pain relief. The majority of radiopharmaceuticals used for therapy are gamma-emitters, but are selected for their β^- emission properties. The following table lists some of these radiopharmaceuticals[11]:

Radiopharmaceutical	Half-life [days]	Gamma ray energy [keV] (% abundance)
^{32}P-phosphate	14.3	N/A (0.0%)
^{89}Sr-chloride	50.5	910 (0.01%)
^{117m}Sn-DTPA	13.6	161 (86%)
^{131}I-BDP	8.1	374 (82%)

[11] Adapted from Sandler *et al* 2003 Diagnostic Nuclear Medicine

Na-^{131}I	8.1	374 (82%)
^{153}Sm-EDTMP	1.9	103 (28%), 41 (49%)
^{186}Re(Sn)-HEDP	3.8	137 (9%)
^{188}Re(Sn)-HEDP	0.7	155 (10%)

In the case of ^{131}I therapy for thyroid disorders, depending on the amount of radiopharmaceutical used, the hospital may employ special precautions for the patients to minimize exposure to themselves, other family members and the general public. These precautions serve as a useful starting point to plan on dealing with a radiological terrorism incident in which casualties have received substantial internalized activity. It is also important to note that these practices are employed routinely in many larger hospitals, and have been shown to be practical given the resources available in a hospital. These practices can be easily adapted to be responsive to radiological terrorist events, although they are not specifically designed to deal with radionuclides other than those used in radionuclide therapy. They are detailed as follows:

5.2.1 Selection of appropriate rooms and their preparation

Minimizing dose to all staff and other patients must be considered when selecting an appropriate room. In addition, many of the exposed patients may become immunocompromised due to biological effects of radiation, thus requiring clean "isolation" rooms. For these reasons, the best choice is usually a corner room with two exterior walls, and with the interior walls being adjacent to rooms with low occupancy factors, such as storage rooms or staircases. The patient must have a private room with private toilet and bath facilities. In most cases, the highest concentration of radionuclide will be excreted in the urine and/or feces with a radionuclide specific excretion rate. Additional amounts will be present in the saliva and perspiration, therefore many surfaces are likely to become contaminated (bed sheets, pillows, night tables, floor, telephones, food trays, many surfaces in the bathroom). These surfaces should all be covered with plastic or absorbent sheets to simplify decontamination after the patient has been discharged. Finally, the patient's door must have a sign designating the room as containing radioactive materials (ie. a "Therapy Room"). Instructions should be posted indicating that all visitors must contact the ward staff prior to entering the room, and that the room cannot be released for general purposes without authorization of the RSO.

5.2.2 Proximity surveys of dose rates

Once the radioactive compound has been administered to the patient, or determined in the event of a contaminated patient, the dose rates in all surrounding areas should be measured. This includes adjacent rooms and hallways, including those above and below the patient's room. Dose rates must be below those permissible in unrestricted areas, so that no member of the public (which includes other patients) will receive a dose of more than 1 mSv per year.

5.2.3 General care of the patient

If the patient is medically unstable and requires monitoring of vital signs, monitoring equipment should be reserved for exclusive use with that patient to avoid contamination beyond the patient's room. If the patient is medically stable, then the routine monitoring of the patient's vital signs should be discontinued in order to reduce dose to staff; and any interaction with the patient should be done from as far away as possible (for example, standing near the room entrance when speaking with the patient, and approaching only when absolutely necessary).

Nurses and staff must wear their radiation dosimeters when entering the patient's room. Protective clothing should also be considered, such as disposable gloves, aprons, and isolation gowns – this is also beneficial to patients who may require isolation to minimize possibility of infections. Disposable gloves must be removed and placed in radioactive waste containers when leaving the room. If staff duties are likely to cause the protective clothing to become contaminated, their isolation gowns must be placed in specially-marked contaminated linen containers in the patient's room until released by the radiation safety officer. Further, used linens and patient clothing must not be sent to the laundry, but must also be placed into decay bins. If there is a spill of excrement, or a medical emergency occurs, or the patient dies, then the attending Nuclear Medicine physician and RSO must be notified promptly. Finally, all food should be served with disposable utensils and plates that can be easily discarded into radioactive decay bins after every meal.

5.2.4 Radiation Safety Instructions to Patients

The patient should be provided with a basic understanding of radiation protection principles. These general principles include not leaving the room and generally minimizing contact with other people. Hygiene must be emphasized: hands must be washed frequently, male patient should sit while using the toilet, the toilet should be flushed several times, and the washroom should not be shared. Further, patients should be encouraged to drink extra fluids to increase clearance of radionuclide uptake.

5.2.5 Radiation Safety Instructions to Visitors

Visitors should be informed of the containment and exposure hazard and be instructed to remain outside the patient's room or wear protective clothing and remain at or beyond a safe distance (as determined by the RSO) from the patient during the visit. No direct patient contact should be permitted. Pregnant women and children younger than 18 years should be discouraged from visiting the patient in the hospital.

5.2.6 Discharging the patient

The patient can be discharged when the following conditions are met [12]:

[12] Regulatory Guide C-292 / Canadian Nuclear Safety Commission / April 2002. Also found in INFO-0442 Guidelines on the Management of Patients Treated with Iodine-131.

- If the activity remaining in the patient after treatment is less than 300 MBq and the approximate radiation dose rate at 2 m is less than 4 μSv/h, no hospitalization and only minimal precautions are required.
- If the activity remaining in the patient after treatment is less than 1100 MBq and the approximate radiation dose rate at 2 m is less than 16 μSv/h, precautions should be taken, whether the patient is hospitalized or released.
- However, if the activity remaining in the patient after treatment is greater than 1100 MBq and the approximate radiation dose rate at 2 m exceeds 16 μSv/h, the patient should be isolated in the hospital, and strict precautions implemented to limit the exposure of other persons.

5.2.7 Decontamination of the patient's room

Following the patient's discharge, all protective covering and garbage are to be disposed of as radioactive waste. The room must be decontaminated and surveyed before it is released for routine use. The room can be surveyed with a Geiger-Muller survey instrument with a thin window pancake probe and with swipe tests.

6. Emergency Response

6.1 Deployment in Ontario

As of December 2005, the Canadian Nuclear Safety Commission has issued 84 licences in the province of Ontario for Diagnostic Nuclear Medicine[13]. Some facilities hold more then one licence. Facilities with full-time Nuclear Medicine physicians and technologists capable of providing meaningful assistance in responding to a radiological incident are listed in Annex C. Of these facilities, four have research capabilities and are staffed with full-time physicists. The majority of the other licensees are stand-alone facilities with negligible capabilities in responding, and many will not have a full-time Nuclear Medicine physician or physicist in attendance.

Given the presence of these assets, it is useful to consider their geographic distribution across Ontario as an estimate of response capability and response gap. Figure 8, below, shows the distribution of the 20 facilities. Hamilton, London and Toronto represent more than one facility. From this distribution, we demarcate "expertise coverage zones" as regions within 30 minutes driving distance of the nuclear medicine facilities. These zones are presented for the southern portions of the province. Detailed maps for four highly-populated regions in Ontario: London-Middlesex, Golden-Horseshoe, Toronto and Ottawa are presented in Annex C.

[13] Licence list retrieved from Canadian Nuclear Safety Commission Website on 12 December 2005.

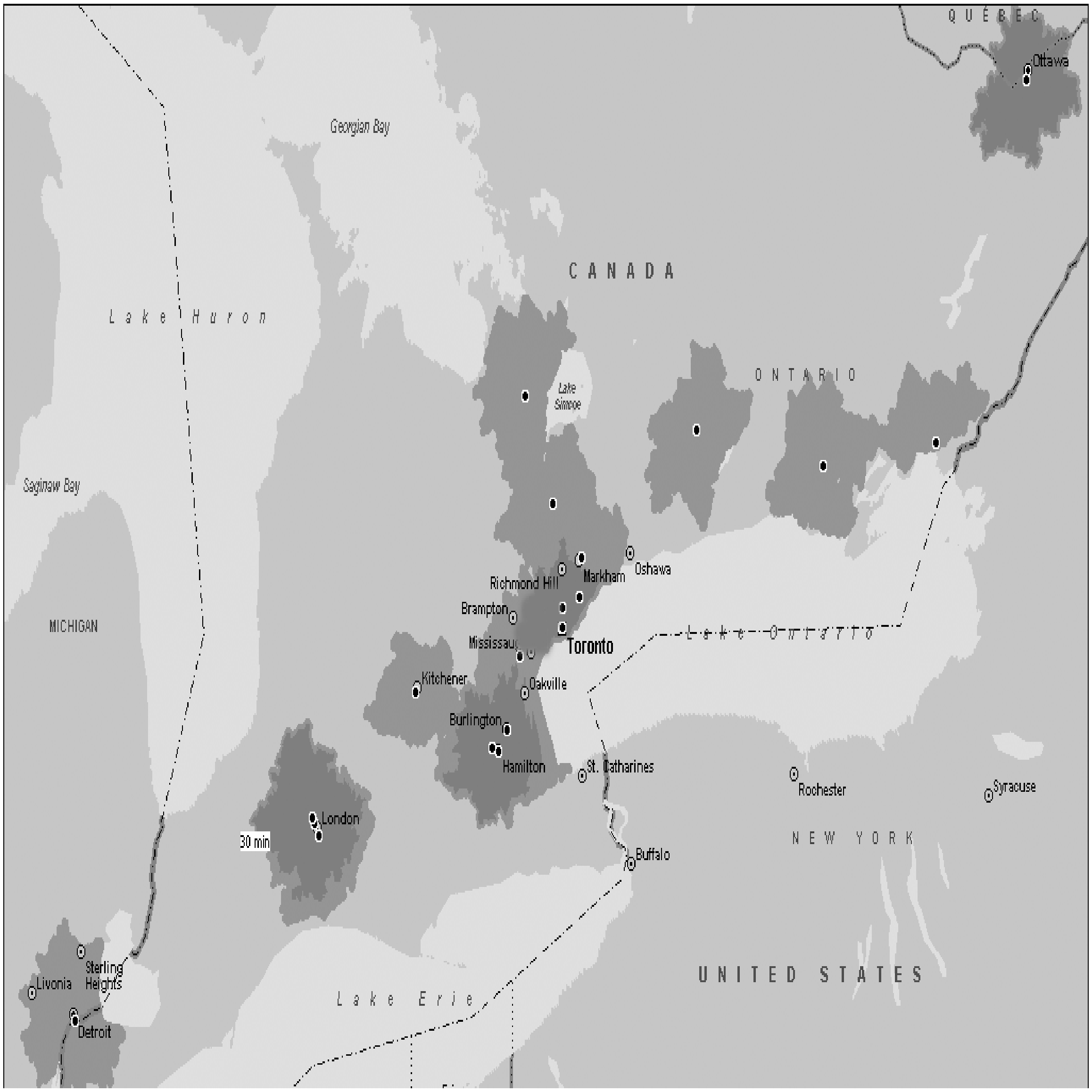

Figure 8: Map of Southern Ontario showing distribution of hospital-based Nuclear Medicine facilities (•). Note that two additional facilities are not shown here: Sudbury and Thunder Bay. Additional details regarding the facilities, contact information for each facility, and more detailed maps are found in Annex C. Surrounding each facility in light grey is the 30-minute drive zone for facilities staffed with nuclear medicine physicians. The dark grey zones represent the 30-minute drive zones for facilities having full-time physicists on staff (London, Hamilton, Toronto, Ottawa). Drive zones are based on average day-time traffic patterns and road layout.

It is important to note that these facilities are distributed according to population density, which may be proportional to the likelihood of a terrorist attack aimed at a population. Figure 9 below shows the 2005 predicted population density in Ontario.

Figure 9: Population density projected for 2005, divisions by census-area. Hospital-based Nuclear Medicine facilities (black dots) are deployed according to population density.

The above two figures demonstrate that hospital-based Nuclear Medicine expertise covers nearly all areas in Ontario where increased population density is found, with an exception of regions around St Catherines near the United States border. Coverage for physics support is sparse, with noticeable gaps west of Hamilton and east of Toronto.

6.2 Education

Although there is considerable multi-disciplinary expertise in nuclear medicine professionals in radiation physics and health effects, there is little to no training in responding to terrorist scenarios. Yet, it is broadly recognized that providing such training to medical staff is imperative

[Waeckerie *et al* 2001, Franz *et al* 1997, Tucker 1997, Richards *et al* 1999, Danzig and Berkowsky 1997]. By formally incorporating such training into educational curricula, the potential problems of creating a rarely used divergent system that is ineffective at best and harmful at worst can be avoided [Waeckerie *et al* 2001]. Over time, incorporation of formal Weapons of Mass Destruction (WMD) training will also benefit emergency response planning and expand and improve response, surveillance, and diagnostic systems. Such improvements will also enhance the medical community's response to other public health crises, such as those involving hazardous materials and infectious diseases [CDC 1998].

Education can take place in a variety of formats, ranging from casual seminars at conferences, to courses providing Continuing Medical Education (CME) credit, to formal education as part of a university-based program. Coleman *et al* [2003] advocate for day-long tutorials before or after annual meetings of professional societies, as well as specialty workshops and meetings. This has been adopted to some extend, with courses or lectures being recently available through the Society of Nuclear Medicine, the Radiological Society of North America, and the Radiation Research Society. Providing education that is more formal will not be without its challenges. Waeckerie *et al* [2001] indicate barriers to providing CBRN counter-terrorism-related education to Emergency Physicians that would extend to the Nuclear Medicine professions:

- No approved body of content exists upon which to base CBRN counter-terrorism content development;
- The need for training has not been broadly articulated and emphasized by national organizations;
- No advocates have been identified to lobby for or influence the acceptance of CBRN counter-terrorism content as a priority for integration into existing medical school or residency curricula, or at professional conferences;
- Lack of funding for the development of CBRN counter-terrorism content;
- Lack of a national repository for the collection of related knowledge to ensure consistency and minimize redundancy of effort;
- Difficulty of procuring adequate expertise to develop suitable curricula;
- Inadequate funding to cover attendance costs (time-off, tuition, travel);
- Failure of hospital administrators to recognize CBRN counter-terrorism training as a priority;
- Failure of physicians to recognize a need for CBRN counter-terrorism education; and
- Personnel shortages make it difficult to cover positions while people are being trained.

6.3 Psychological Consequences and Public Communications

Much emphasis has been placed on evaluating the nation's security gaps, response capabilities, and overall preparedness by technological and administrative success. Yet, terrorism is designed specifically to have a psychological impact, and has the potential to pose serious and long-lasting social, psychological and behavioural changes [Willis and Coleman 2003, NCRP 2001]. Indeed,

psychological effects may be the major consequence of radiological terrorism [NCRP 2001, Neagle 2003]. These consequences – often not modeled in tabletop exercises – may multiply the resources needed to effectively manage a situation. Several examples are in order:

- Gulf War: In Emergency Room admissions, only 22% of personnel had physical injuries related to blasts following Scud missile attacks. Another 22% of treated personnel used their atropine auto-injectors unnecessarily – thinking they had been exposed to nerve gas; and another 51% of admissions were personnel who could not cope with the anxiety and panic associated with these missile attacks [Salter 2001].
- Chernobyl: Following the 1986 nuclear power plant accident, people across the world feared fallout moving into their living environments. Some refused to go outdoors, eating only canned foods. Some living in nearby countries committed suicide to prevent what they believed would be a radiation-induced death [Salter 2001].
- Goiania: Following the accidental ^{137}Cs release in 1987 over 125,000 people reported for contamination screening at local hospitals and emergency monitoring facilities, but only 249 were found to be contaminated [Steinhausler 2005, IAEA 1998].

On a longer time scale, general fear could spread through a population regarding groups of potentially exposed individuals or areas of land [Becker 2005], ultimately increasing general stress-induced morbidity and reducing the ability of the government to maintain public confidence [NCRP 2001]. Therefore, it is of paramount importance that aspects of response consider both technical requirements as well as psychological aspects, to deal with both physical and psychological casualties.

Good risk communication can go far in mitigating the fear and panic in the population [Pellmar and Rockwell 2005]. Communication will have a profound impact on the public's reaction to a radiological event and the government response capability [NCRP 2001]. Two issues are then: Who is to do the communicating? And, What is the information to communicate?

The question of who is to convey information to the public – or to an individual victim – can be as important as the information itself. A recent public opinion poll in the United States asked the question of who to trust to give reliable information in the event of a terrorist attack. This poll indicated that a "Doctor who is an expert" would be trusted more (83%) than the US Surgeon General (76%), the Secretary of the Department of Homeland Security (68%), or the President of the United States (65%) [Becker 2005]. Turning to physicians who are experts suggests relying on radiologists, oncologists, and Nuclear Medicine physicians. Whereas all three groups have excellent knowledge of biological effects of ionizing radiation and general radiation protection, Nuclear Medicine physicians may have the most comprehensive experience in matters of external decontamination, internal decorporation, use of survey equipment, and use of select countermeasures such as potassium iodide and other decorporation agents.

In the event of a radiological incident, medical professionals will be called upon to talk to the public about health risks and available countermeasures. Although their opinions will likely be perceived as credible [Becker 2005], the communication will only be effective if these professionals have the skills necessary to convey complicated ideas clearly and effectively to non-specialists [Pellmar and Rockwell 2005]. Speaking extemporaneously either in front of a television crew or during an evolving emergency is stressful. Thus, it is useful to have developed

messages prior to an event, as recommended by NCRP [2001]. A sample of questions and answers is presented in Annex A, based on material found in nuclear medicine textbooks.

6.4 Contribution to Emergency Department Procedures

Effective assessment and countermeasures strategies require the development of a formal Radiological emergency response plan. The staff of an Emergency Department is accustomed to the frequent treatment of chemical injuries, arising from inhalation of noxious aerosols, ingestion of poisons, or dermal exposure to corrosive materials. Thus, staff has an appreciation for oral, tracheal, bronchial, and alveolar deposition of particulates; intestinal absorption of materials; and cleaning of contamination from wounds. As such, only slight modifications – to emergency patient management – would be required to expand these plans to deal with scenarios that include a radiological component. Here, a Nuclear Medicine staff would be invaluable in lending guidance to protocols for triage, initial cleanup of contaminated wounds, stockpiling of pharmaceuticals for emergency intervention (such as potassium iodide), and consultation with specialists. Identification and application of critical biodosimetry methodologies will result in improved treatment strategies. The National Biological Dosimetry Response Plan (NBDRP) developed by DRDC Ottawa in partnership with Health Canada, Atomic Energy of Canada Limited and McMaster University is available to provide this biodosimetry consultation [Wilkinson *et al* 2006].

A core component to the emergency plan is efficient transformation of the Emergency Department into a facility that can receive contaminated casualties, identify their contamination (to facilitate triage), and limit its spread, while maintaining safety practices consistently. Some experience has been gained with SARS, while growing fears of pandemic influenza ensure increased vigilance and review of emergency procedures. Preparing a department for dealing with a radiological emergency, however, has some important differences. For example,

- Unlike a virus, the presence of radionuclides can be immediately detected with appropriate equipment. As such, staff and patients can be moved across an appropriately monitored dirty/clean line without fear of endangering others
- Staff exposure to radiation can be quantified, and staff should be rotated to minimize exposure
- Removing clothing from contaminated individuals can substantially reduce contamination (by about 90%)
- Radioactive material cannot be destroyed by any chemical means, but it does decay with time, and it can be shielded against
- Patients who are not contaminated but may have been irradiated from an external source may present symptoms that are non-specific to radiation injury, making the extent of their injury and prognosis difficult to characterize.

Ideally, the Emergency Department will be sectored into dirty and clean areas, with a trained monitoring team controlling traffic across the interface – and discouraging staff from frequent crossings. Appropriate precautions should be taken within the dirty area to allow for easy cleanup of contamination, while maintaining procedural efficacy. For example:

- any unnecessary equipment should be removed from the dirty area prior to receiving patients
- a portable x-ray machine can be brought in for emergency x-rays
- the surfaces of the controlled areas should be prepared with material that allows for easy cleanup
- contaminated clothing should be double-bagged in polyethylene bags and labelled, and moved into a storage facility to reduce background exposure
- bathrooms should be monitored frequently.

These types of precautions are regularly taken in the ^{131}I treatment of thyroid cancer patients who remain in hospital during the early phase of their treatment (See Section 4.3). Here, a Nuclear Medicine physicist should be consulted in developing procedures for maintaining radiation safety while other staff delivers patient care. The task of the Nuclear Medicine physicist would include selection of appropriate instrumentation for radiation surveys (such as proportional counters or Geiger counters) and staff monitoring (such as personal dosimeters), identifying appropriate equipment for limiting spread of contamination (such as materials to cover surfaces and equipment, and creating spill kits), delineating boundaries for clean/dirty lines, and developing guidelines for limiting staff exposure.

Managing an Emergency Department divided by a dirty/clean line, with policies that restrict movement of personnel, require frequent surveys. General containment of radioactivity will require a large, highly-trained staff; preferably a staff that has day-to-day experience with radiation protection. The most appropriate staff for this task are Nuclear Medicine technologists, all of whom are designated as Nuclear Energy Workers (unlike physicists and physicians), and deal with the most open-source radioactive material of any staff in the hospital.

In planning for the Emergency Department's management of radiological incidents, undoubtedly questions from the staff will arise. The interpretation of technical data has always presented problems for professionals and lay persons not involved in their development. This problem is compounded when the data are needed to make rapid decisions in a dynamic emergency response environment. Given public perception of ionizing radiation and nuclear material, it is important to instil confidence in staff that procedures are being developed in consultation with knowledgeable specialists who have access to texts and a working knowledge of web-based resources, and government and professional societies who can lend assistance. Further, it lends additional credence to the process if those specialists have a vested interest in the outcome of the plans and their execution during a crisis (*i.e.* hospital staff).

7. Case Study: Anytown, Ontario

Tabletop exercises have often been conducted from a top-down perspective, involving mostly federal representation. However, it is useful to also consider a bottom-up effort to gauge how a municipality would coordinate its own resources in responding to a terrorist incident, and how a municipal response would best interface with federal capabilities.

The hypothetical city of Anytown – modeled after a city in Southwestern Ontario – conducted a Tabletop Exercise to evaluate its response capabilities and shortfalls. Although the exercise assumed a chemical attack, it is included here to understand how a municipality would plan for dealing with a CBRN attack, and what effort would be required to expand their planning to include dealing with an ‘R’ threat.

The city of Anytown has a population of approximately 400,000, and covers a landmass of approximately 3000 km^2. Anytown is serviced by four major teaching/research hospitals, each with its own emergency department and nuclear medicine department. The nuclear medicine departments are collectively staffed by 9 physicians, 24 technologists, 3 physicists, and 2 radiopharmacists.

7.1 Interfacing Hospital Support with City Capabilities

Much of the planning is done through the City’s Working Group for Health Emergencies, whose mandate is to develop “all-hazards” plans for responding to large-scale incidents, such as CBRN incidents and influenza pandemics. Their planning involves review of the current level of preparedness, identifying the gaps in the current response capacity, and putting plans in place to address the gaps. The plans are to be integrated with federal and provincial emergency response plans. The composition of the Working Group includes members from the municipal government, fire department, police department, local hospitals, and the city’s university. Currently, the focus of the city is to complete its plan for responding to influenza. Although this plan is comprehensive, it is designed to address a threat that would manifest gradually and with substantial warning. The plan would require extensive modification to address incidents that occur on a short time scale, such as chemical or radiological terrorism incidents.

7.2 City Response Capabilities and Training

7.2.1 Tabletop Exercise

To evaluate the capabilities of Anytown to respond to a CBRN event, a tabletop exercise was conducted that simulated a chemical attack at a train station on a busy day. Several of the participants attended the First Responder Training for CBRN Events (2001), which provided some background into the nature of CBRN events and related tabletop exercises. The particulars of the hypothetical incident were as follows:

Date: Major holiday (Christmas)

Location: Train Station, downtown Anytown

Time: 5:00 pm

Victims: 400

Participants of the tabletop exercise included representatives from the local police and fire departments, ambulance service, and hospital. The exercise provided valuable information regarding the shortcomings of first responders and hospitals.

7.2.2 Anytown Police Department

The Anytown Police Department has 500 officer and 175 support personnel. Based on the tabletop exercise, it was determined that all police require awareness-level training to improve their understanding of CBRN terrorist incidents, and a subset would acquire advanced CBRN training. Personal Protection Equipment (PPE) would be procured for 15% of police. Next, Sergeants would receive Incident Commander Training (available from Canadian Emergency Preparedness College (CEPC)). A shortfall was identified in terms of being able to identify the nature of the (chemical) threat; thus it was recommended that a Chemical Agent Monitor (CAM) be purchased for Anytown.

7.2.3 Anytown Fire Department

The Anytown Fire Department has 300 fire fighters and 50 support personnel, distributed across 10 stations with 20 trucks. They also operate a Hazardous Materials (HAZMAT) team. Shortfalls in response capabilities of the Fire Department were identified in several areas. The first area to be enhanced was training: CBRN awareness training was indicated for all personnel, and advanced CBRN training was indicated for all HAZMAT members. Improved coordination with the police department and (Emergency Medical Services) EMS was deemed necessary: common radio interoperability, a closer relationship with police receiving advanced CBRN training, and joint training with police and EMS. The local university was identified as having expertise that could aid in identifying CBR materials, and so it was identified as a valuable reach-back resource. Finally, as with the police department, additional equipment was needed, particularly a CAM.

7.2.4 Anytown Emergency Medical Services (EMS)

The Anytown EMS employs 150 paramedics, and has 20 ambulances. EMS was deemed to have a significant shortfall in terms of training. Thus, all paramedics were to receive CBRN awareness training, and a specialized group would receive advanced CBRN training and Incident Commander Training. Additionally, equipment deficiencies were identified: notably a lack of PPE and equipment for mass casualty management (including portable shelters).

7.2.5 Hospitals

Hospitals were ill-equipped to protect against contamination. To mitigate this possibility, hospitals would require early warning from first responders regarding the nature of the incident,

the nature of the CBRN agent, and the number of people exposed. However, hospitals must ultimately improve their ability for decontamination (via improved training and equipment procurement), and cannot rely on fire departments or EMS to assist in a time of crisis. Hospitals must also improve their internal security and patient-flow patterns by installing improved door-locking mechanisms to control entrances and designating isolation areas. Finally, medical and security staff are all to receive CBRN awareness training.

7.2.6 Joint Recommendations

Several recommendations were made that would address shortfalls across most departments. The first was that improved CBRN training was necessary, both at the awareness level for all, and at the advanced level for a smaller group. Secondly, improved equipment was necessary for all departments, be it for identification of hazardous materials, improved decontamination, or improved casualty management. Thirdly, that all departments acknowledge that a CBRN incident could occur within their jurisdiction, and that they would undertake steps necessary to provide uninterrupted emergency services to the citizens of Anytown. Also identified was the lack of awareness training for the general public. Although such training should be promoted with sensitivity and caution, providing at least some level of education may reduce the psychological burden of a terrorist attack, as well as enhance public confidence in the actions of authorities during times of crisis.

7.3 Analysis

The tabletop exercise, although providing much needed information regarding strengths and weaknesses of Anytown response capabilities, was focused on responding to a Chemical incident. It is important, however, to consider several fundamental differences between a chemical incident and a radiological incident. First, the time-scale of a chemical attack can be much shorter than a radiological attack: winds can dissipate aerosols within tens of minutes. A radiological attack can either be instantaneous (such as an explosive radiological dispersal device), or stealthy, such as an abandoned source covertly placed in a public area. In either case, decontamination of structures will require some intervention, unless the radiological material has a short half-life (<months). Second, it is relatively easy to differentiate exposed individuals from non-exposed in a chemical attack, where symptoms could manifest within seconds. In a radiological attack, however, unless the individuals are contaminated or the exposures very significant (>1Gy), it may be difficult to identify victims from non-victims, and it is therefore expected the population of Anytown may experience more psychological stress over the long-term. Given these differences, it would be of value to repeat the tabletop exercise, this time focussing on a belligerent radiological incident.

In order to improve preparedness for identifying and responding to a large-scale radiological incident, the city of Anytown requires: (a) improved awareness of the radiological threat, and (b) improved connectivity with resources useful in responding to radiological incidents. Awareness should come from a federal level, where efforts are specifically directed to addressing the concerns of radiological terrorism. Connectivity, on the other hand, can come from all levels: from specialized expertise and equipment available at local hospitals, to federal capabilities extended across the country. Realizing these two requirements would likely require some support from the federal government. For example, an “Educational Session” could be organized to inform city officials, first responders, emergency departments, and nuclear medicine staff of the

nature of radiological terrorism and indicate how local assets could be used to mitigate the impact of such events. Also, most recent information on available therapeutic radioprotectants needs to be disseminated and regularly updated.

8. Conclusions

Substantial effort has been directed towards radiological counter-terrorism in terms of technology development and planning on a federal level (CRTI). However, important work remains to be done in recruiting the substantial pool of nuclear expertise in Canada. With the intent of improving coordination of federal capabilities with Nuclear Medicine professionals, we summarize our findings with the following recommendations directed at federal planners:

- Recognize that significant assets are in place for mitigating the physical and psychological injury associated with radiological terrorism. However, specific guidance for health-care professionals on radiological counter-terrorism is lacking.
- Improve the coordination of top-down tabletop exercises with bottom-up tabletop exercises. Municipalities would strongly benefit from an understanding of federal capabilities and response strategies.
- Develop training materials for providing radiological terrorism awareness to hospital staff already possessing significant radiation protection expertise.
- Establish a formal point-of-contact with nuclear medicine professional societies.
- Develop a national database of nuclear medicine assets, including expertise and equipment.
- Improve nuclear medicine community awareness of the potential for a radiological terrorist incident. Develop and implement Continuing Medical Education (CME) – accredited sessions at national conferences, with the intent of enlisting support.

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Annex A Anticipated Questions arising from Radiological Emergencies

These questions and answers may seem obvious; nevertheless, it is important to have prepared responses that are not inflammatory but are also not dismissive of people's concerns (for example, terms such as "radiophobia" should be avoided [Becker 2005]). Portions of this material are adapted from "Responding to the Media in Emergencies" *J Nucl Med* **44** 12N-16N; "Disaster Preparedness for Radiology Professions" www.acr.org; Saha GB "Physics and Radiobiology of Nuclear Medicine 2nd Ed" 2001 Springer-Verlag New York – references typically found in Nuclear Medicine Departments. Thus, nuclear medicine staff would anticipate these types of questions, and might provide the corresponding answers.

What is radiation? Where does it come from?

Radiation is energy. We are exposed to it every day from the sun, the earth, and even from small amounts of radioactivity in our foods and inside our bones. It's used in our society in many ways: in smoke detectors, and by dentists and doctors who take x-rays. The unit of radiation dose is the Sievert. This is used to measure how much radiation we are exposed to. For example, in Canada people are exposed to a few mSv of background radiation but this can vary depending on the location and the altitude at which you live. The amount of radioactive material is measured using a unit called the Becquerel. If radioactive material, such as uranium, is released into the environment, then this contamination can be measured in terms of Becquerels. In the event of a radiological emergency, such as an accident or a terrorist event, it is important to determine whether a person has been exposed to a radiation dose, or has become contaminated with radioactive material. In the case of contamination, it is important to determine whether that contamination is just outside the body, or if it has gotten into the body (either by breathing, or drinking, or eating, or through an injury).

How could somebody be injured from a dirty bomb?

People can be injured from radiation in several ways. At low doses, radiation injures DNA within the cells, which could lead to cancer over long periods of time (years), and could be detrimental to fetuses carried by pregnant women. At higher doses, health effects include nausea, reddening of the skin, diarrhoea, and death. The length of time it takes for these symptoms to appear depends on dose of radiation received and the rate at which the dose is delivered. Several groups of medical staff receive small amounts of radiation every day, but are not injured and do not experience any effects. Scientists believe that the amount of radiation released from a dirty bomb would probably be very low, and it is likely that most people exposed to these low amounts will experience no subsequent effects. It is more likely that people may be injured by the explosion of the dirty bomb, and not the radiation.

Does a hospital have the staff and equipment needed to determine if somebody has been exposed to radiation?

Most medium- and large-hospitals have highly trained personnel and sensitive equipment to determine if somebody has received a large radiation dose or has contamination. Some of these

instruments are very portable, and are more frequently becoming part of the equipment carried by Fire and Ambulance crews. This equipment is used to determine whether or not a person has been contaminated, and if yes, where that contamination is, and to monitor the decontamination procedure. In some cases, decontamination can be a simple process, such as showering and changing clothing; and this can be done before arriving at the hospital. Other times, it can be more difficult if the contamination is inside the body. Internal contamination will be treated once the patient has arrived at the hospital.

How would a hospital deal with casualties of a radiological incident?

Most medium- to large-hospitals are developing – or already have – plans in place to deal with large-scale catastrophes, be they accidents to terrorist events. These plans include aspects of coordinating with first responders (police, fire, and ambulance crews), and training of staff to deal with contamination on-site. Although most hospitals do not have enough funding to be completely prepared for large-scale events, they do have lines of communication to provincial and federal sources of aid.

Can you give me an example of what might occur in a "dirty bomb" attack?

In 1987, an incident occurred in Brazil that most experts believe best resembles how a dirty bomb would impact a population. In that incident, a large radioactive source (^{137}Cs) was accidentally removed from its protective casing and brought into the community. There were four casualties, and approximately 125,000 people showed up at local hospitals and other specialized facilities for screening. This response completely overwhelmed the existing medical response capabilities. Only 249 people were contaminated, most receiving only mild exposure at about the level of a routine x-ray. More than 110 blood samples from persons affected by the accident were analysed for evidence of cytogenetic damage. It took three months to clean up the contamination.

Which personnel are specially trained to treat patients in such emergencies?

There are a variety of different personnel trained to deal with "dirty bombs" and victims of radiological incidents in general. These days, many fire departments have specially trained Hazardous Materials (HAZMAT) teams that carry equipment to detect radiation. Within hospitals, nuclear medicine physicians and technologists routinely use radioactive material to diagnose brain and heart disease and cancer, and to even treat cancers. Nuclear Medicine physicists have specialized training in measuring radiation and can provide expert advice on the probable effects of radiation exposure. Further, these physicians, technologists, and physicists use, on a daily basis, highly sensitive equipment that detects radiation. They also have the necessary resources to decontaminate people.

If I help somebody who is a victim of a dirty bomb, can I get injured from radiation from that person?

There are two aspects to consider. First, if somebody is contaminated with radioactive material, then that contamination can spread to other people. If the contamination is on the outside of their body, their clothes should be removed and they should take a shower. This procedure will remove most surface contamination. Also, they should avoid close contact with people (hugging, etc…) for several days. However, if they have breathed in radioactive dust, or swallowed radioactive

material, they should report to a hospital immediately. Second, if that person has been exposed to radiation, but they are not contaminated, then that radiation dose cannot be passed onto anybody else.

Would children and pregnant women receive extra care?

The cells that are most sensitive to the effects of radiation are those that divide the most. Therefore, the cells in a fetus are especially sensitive to the effects of radiation. If a woman believes she may be pregnant, she should always report that to medical staff so that they can evaluate what effect that dose – or their treatment – might have on the fetus. Children, too, have increased sensitivity to radiation. Fortunately, the expertise and equipment that is used to evaluate adults is the same as for children. Treatment strategies for children and adults are the same, however the treatment doses may differ. Medical staff always thoroughly evaluate everybody who is a victim, and will decide on how to prioritize treatment.

I've heard that potassium iodide may be useful in a radiological emergency? Is this true?

In the event of a contamination arising from a nuclear power plant, or a nuclear explosion, large amounts of radioactive iodine may be released. If this radioactive iodine enters your body, it will accumulate in your thyroid, which could become damaged. One way to prevent the accumulation of radioactive iodine in your thyroid is to "pre-load" your thyroid with potassium iodine which is not radioactive. Some people, however, have allergies to potassium iodine, and should only take it under the supervision of a physician. Also, unfortunately, potassium iodine only protects against radioactive iodine, and would not protect against other forms of contamination that may arise from the explosion of a dirty bomb that may consist of radionuclides other than iodine. Over the age of 40 years there is a greater risk of an allergic reaction to potassium iodide than there is from developing radiation induced thyroid cancers. For this reason, it is recommended that adults over the age of 40 years do not get treatment with KI unless a very large dose of radioactive iodine is expected.

Annex B Nuclear Medicine Professional Organizations in Canada

Canadian Association of Nuclear Medicine and Canadian Society of Nuclear Medicine
774 Echo Drive
Ottawa, Ontario
K1S 5N8
Telephone: (613)730-6254
Fax: (613)730-1116
Website: www.csnm.medical.org

Canadian Association of Medical Radiation Technologists
10th Floor, 85 Albert Street
Ottawa, Ontario
K1P 6A4
Telephone: (613)234-0012
Fax: (613)234-1097
Website: www.camrt.ca

Canadian College of Physicists in Medicine
P.O. Box 72024, Kanata North RPO
Kanata, Ontario
K2K 2P4
Telephone: (613)599-1948
Fax: (613)599-1949
Website: www.medphys.ca

Canadian Association of Radiopharmaceutical Sciences
c/o Dr Doug Abrams
11560 University Avenue
Edmonton, Alberta
T6G 1Z2
Telephone: (780)432-8970
Fax: (780)432-8637
Website: www.radiopharmacycanada.com

Annex C Larger Ontario Hospitals with Nuclear Medicine Capabilities

City	Hospital	Address	Hospital Phone
Barrie	Royal Victoria Hospital	201 Georgian Drive, Barrie, Ontario, L4N 1G4	(705)728-9802
Belleville	Quinte Health Care Belleville	265 Dundas Street East, Belleville, K8N 1E2	(613)969-7400
Brampton	William Osler Health Centre – Peel Memorial	20 Lynch Street, Brampton, Ontario, L6W 2Z8	(905)494-2120
Burlington	Joseph Brant Memorial Hospital	1230 North Shore Boulevard East, Burlington, Ontario, L7S 1W7	(905)632-3730
Etobicoke	Trillium Health Centre – Queensway Site	150 Sherway Drive, Toronto, Ontario, M9C 1A5	(416)259-6671
Hamilton	St Joseph's Hospital	50 Charleton Avenue East, Hamilton, Ontario, L8N 4A6	(905)521-6102
Hamilton	McMaster University Medical Centre	1200 Main Street West, Hamilton, Ontario, L8N 3Z5	(905)521-2100
Kingston	Kingston General Hospital	76 Stuart Street, Kingston, Ontario, K7L 2Z7	(613)549-6666
Kitchener	St Mary's General Hospital	911 Queen's Boulevard, Kitchener, Ontario, N2M 1B2	(519)749-6578
London	St Joseph's Health Care – London	268 Grosvenor Street, London, Ontario, N6A 4V2	(519)646-6000
London	London Health Sciences Centre – Victoria	800 Commissioners Road East, London, Ontario, N6A 5W9	(519)685-8500
London	London Health Sciences Centre – University	339 Windermere Road, London, Ontario, N6A 5A5	(519)685-8500
Markham	Markham Stouffville Hospital	381 Church Street, Markham, Ontario, L3P 7P3	(905)472-7000
Mississauga	Credit Valley Hospital	2200 Eglinton Avenue West, Mississauga, Ontario, L5M 2N1	(905)813-2200
Newmarket	South Lake Regional Health Care	596 Davis Drive, Newmarket, Ontario, L3Y 2P9	(905)895-4521
North York	Sunnybrook & Women's College Health Sciences Centre	2075 Bayview Avenue, Toronto, Ontario, M4N 3M5	(416)480-6100
Ottawa	The Ottawa Hospital – Civic Campus	1053 Carling Avenue, Ottawa, Ontario, K1Y 4E9	(613)722-7000
Peterborough	Peterborough Regional Health Centre	1 Hospital Drive, Peterborough, Ontario, K9J 7C6	(705)743-2121
Scarborough	The Scarborough Hospital	3050 Lawrence Avenue East, Scarborough, Ontario, M1P 2V5	(416)438-2911
Sudbury	Sudbury Regional Hospital – Memorial Site	41 Ramsey Lake Road, Sudbury, Ontario, P3E 5J1	(705)523-7100
Thunder Bay	Thunder Bay Regional Health Sciences Centre	980 Oliver Road, Thunder Bay, Ontario, P7B 6V4	(807)684-6000
Toronto	Mount Sinai Hospital	600 University Avenue, Toronto, Ontario, M5G 1X5	(416)596-4200
Toronto	St Michael's Hospital	30 Bond Street, Toronto, Ontario, M5B 1W8	(416)360-4000
Windsor	Hotel-Dieu Grace Hospital	1030 Ouellette Avenue, Windsor, Ontario, N9A 1E1	(519)973-4444

Four maps are presented below, showing in detail the distribution of hospital-based Nuclear Medicine facilities in four high-population regions in Ontario. Around each facility, in light grey, is the 30-minute drive zone, approximating a "coverage zone" within which on-site specialized medical expertise may become available soon after a radiological incident. Also shown in dark grey are the 30-minuite drive zones for Nuclear Medicine physicists, who could provide expert advice in radiation physics in the event of an incident.

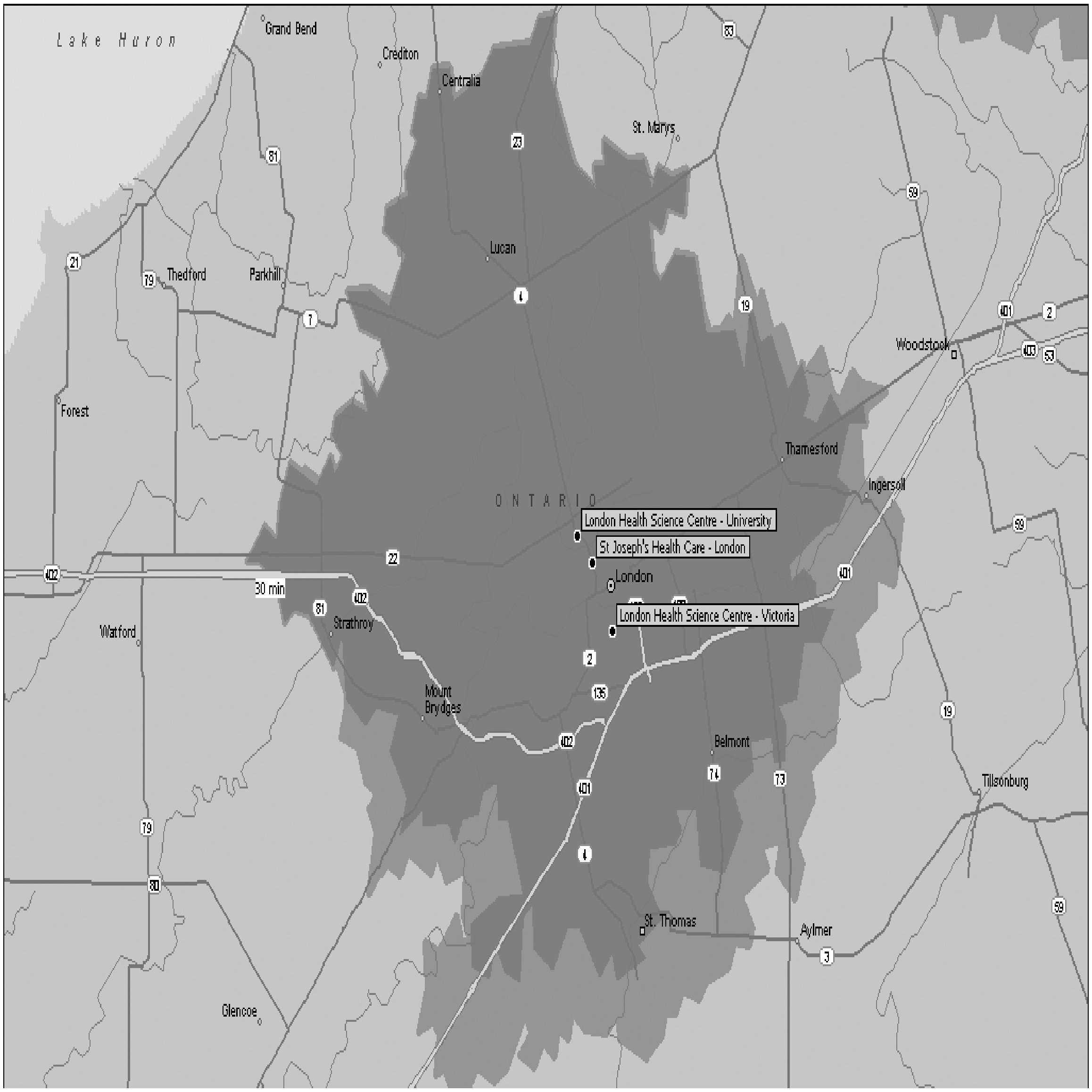

Figure 10: Three major hospitals provide most of the services in the London-Middlesex area. Physics (Nuclear Medicine) support is available from both London Health Sciences Centre – University, as well as St Joseph's Health Care – London.

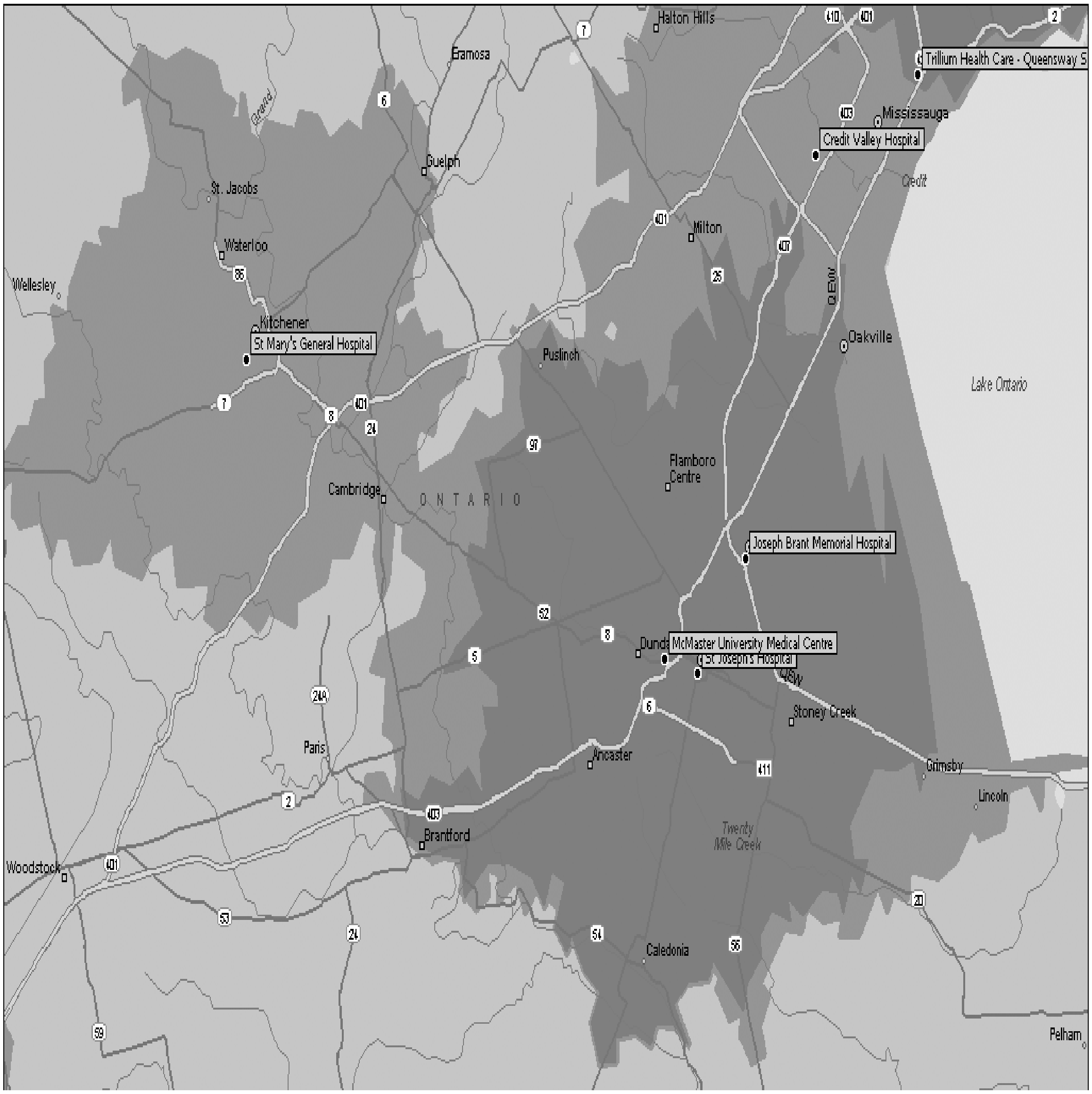

Figure 11: The Golden Horseshoe region of Southwest Ontario is serviced by six major hospitals with Nuclear Medicine capabilities. Physics (Nuclear Medicine) support is available from McMaster University Medical Centre.

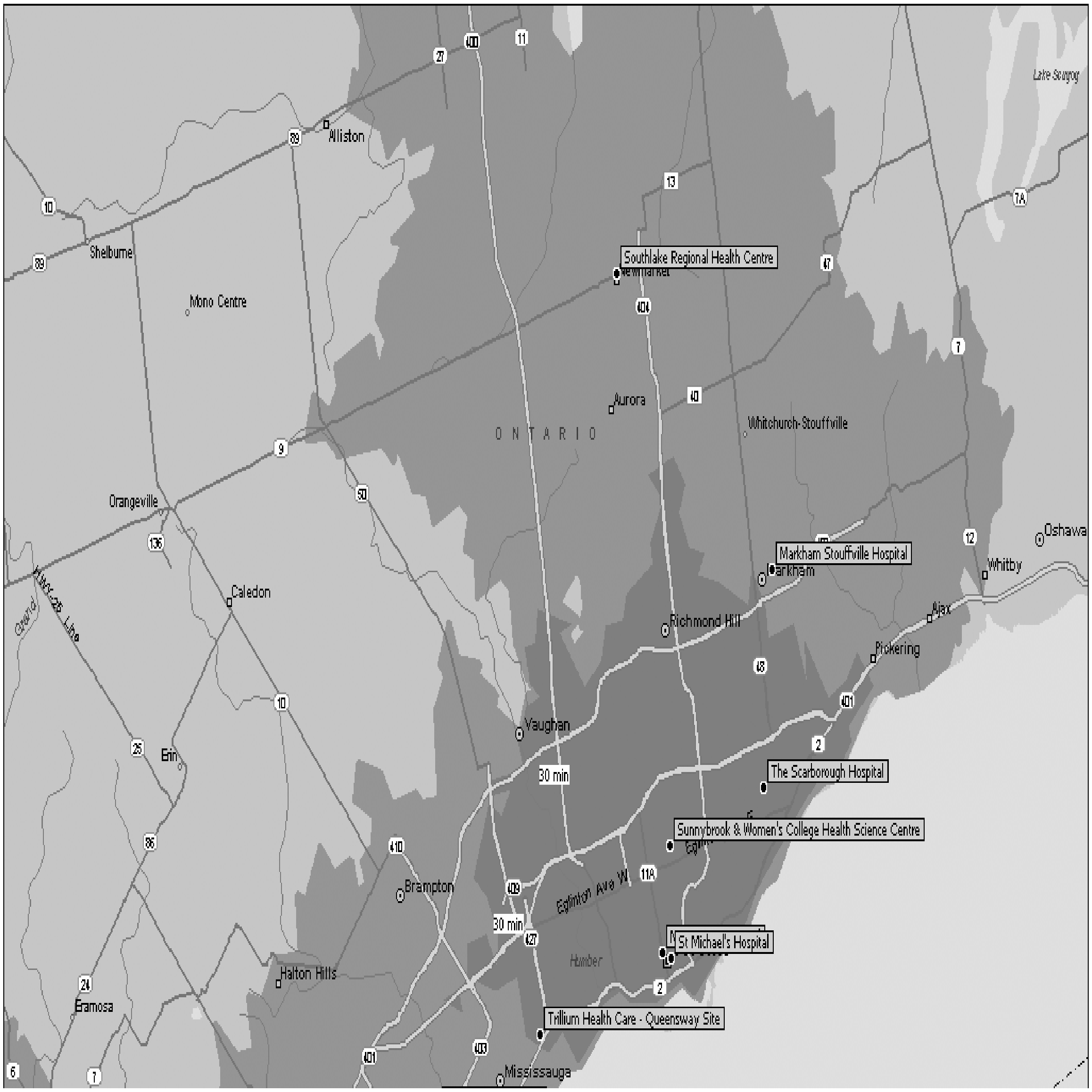

Figure 12: The greater-Toronto area has the largest concentration of Nuclear Medicine capabilities, along with the greatest population. Physics (Nuclear Medicine) support is available from Sunnybrook & Women's College Health Sciences Centre, in North York. Note that the symbol for Mount Sinai is covered by St Michael's Hospital.

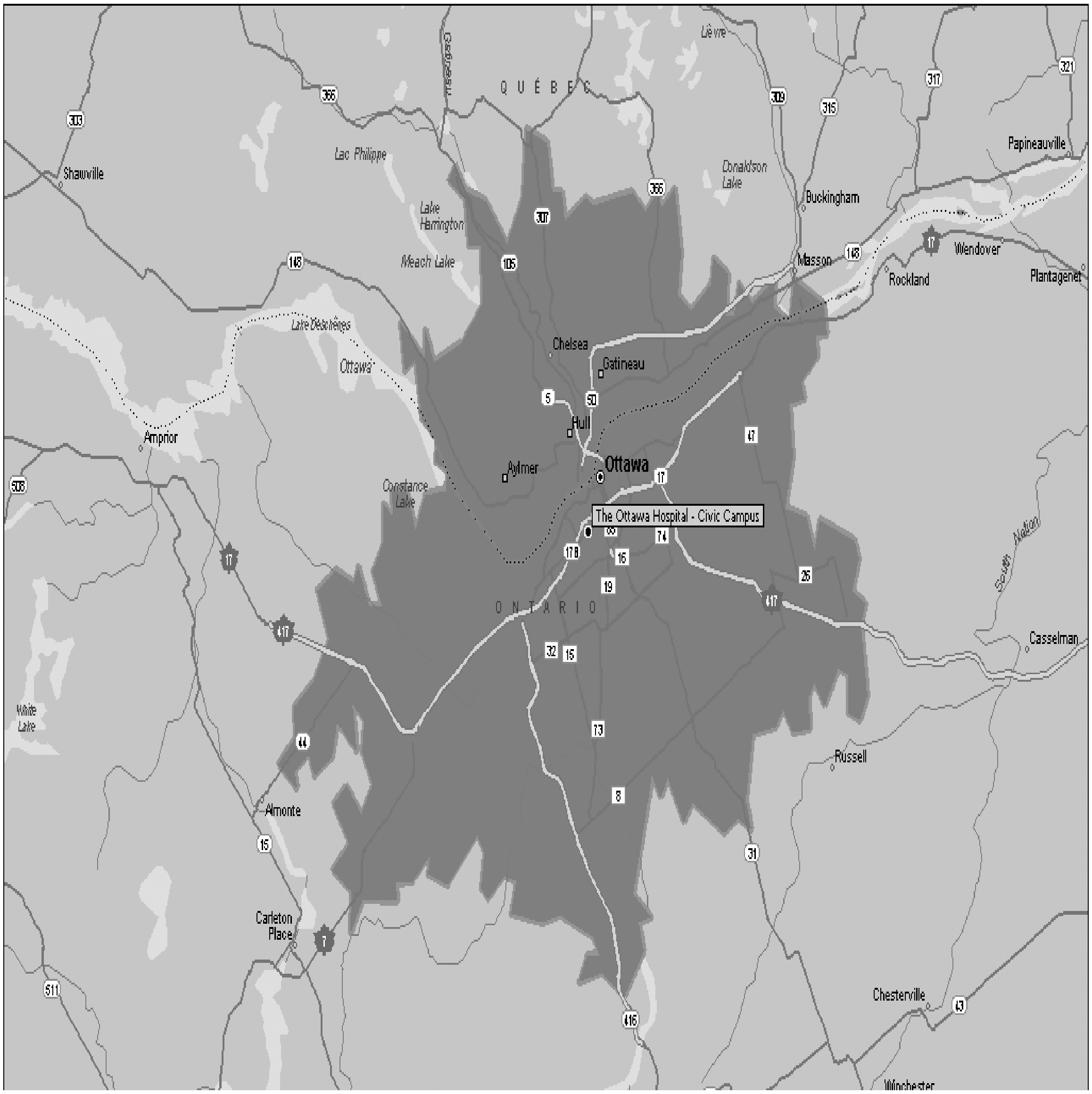

Figure 13: Coverage for the Ottawa area is provided through The Ottawa Hospital, which also has full-time physics (Nuclear Medicine) support.

Annex D Radiation Safety Officer Duties in a Hospital Setting

- Reviews relevant legislation and license conditions, and initiates changes to procedures and facilities in response to changes in CNSC requirements;
- Conducts annual reviews of the Radiation Safety Program, and communicates with all individuals in the program (senior management, team leaders/managers, radiation safety committee, radioisotope users) on matters relevant to radiation safety;
- Controls purchase of radioactive materials, ensuring only authorized persons place orders;
- Conducts annual assessments of conditions set in internal permits issued to labs, implementing remedial actions to correct deficiencies found during internal inspections;
- Designates labs appropriately and maintains records of status of all radionuclide labs;
- Develops, reviews and implements controls and procedures ensuring radiation safety programs are appropriate to the organization's undertakings and comply with regulatory requirements;
- Provides necessary radiation safety information and training to personnel who handle radioisotopes and may be exposed to radiation as part of their duties (nurses, shippers and receivers, fire and safety, maintenance);
- Ensures only qualified/competent individuals use or handle radioactive materials and maintains a list of such individuals;
- Designate Nuclear Energy Workers as required;
- Provides adequate disposal procedures according to conditions of the radioisotope license;
- Designs and maintains personnel contamination monitoring and bioassay procedures;
- Keeps an inventory list of radiation monitoring devices and equipment (e.g. fume hoods, well counters), and records of their maintenance (e.g. yearly calibration certificates);
- Conducts a quarterly review of occupational radiation exposures and recommends to individuals measures to reduce exposures in accordance with the ALARA principle;
- Investigates reports of radioactive spills, overexposures, losses of radioactive material, accidents involving radioactive material and recommends actions to prevent such future occurrences. The RSO also ensures that such incidences are reported to the CNSC in a timely manner;
- Maintains an inventory of all sealed sources, and ensures that sealed sources are leak-tested in accordance with the institution's procedures and regulatory requirements;
- Consults and cooperates with the responsible physician and/or ethical review committee when the CNSC license allows the use of radioactive materials in research, diagnosis or therapy on humans;

- Develops and maintains a plan to be used with respect to an emergency situation involving radioactive materials;
- Ensures that names contact persons for emergency situations and their phone numbers are maintained on all entrances to all facilities housing radioactive materials;
- Ensures that all licenses issued by the CNSC are posted on all corresponding facilities housing radioactive materials;
- Ensures that all required records (e.g. inventory sheets, staff training certificates) and reports (e.g. incident reports) are prepared, maintained (filed up to five years) and submitted (when requested by CNSC); and
- Ensures that only Transportation of Dangerous Goods (TDG Class 7) certified personnel transport, ship, and/or receive packages containing radioactive material.

An example of the experience/knowledge base for an RSO in a nuclear medicine department is as follows:

- Has at least 3 years of relevant work experience;
- Has received formal training in assuring workplace radiation safety;
- Understands the technology and methods to control, use, store and dispose of radioactive material;
- Understands how to monitor and control radioactive contamination, radiation fields an radiation exposures; and
- Understands relevant legislation and license conditions.

References

Augustine AD, Gondre-Lewis T, McBride W, Miller L, Pellmar TC, Rockwell S 2005 Animal Models for Radiation Injury, Protection, and Therapy *Radiat Res* **164** 100-109

Becker SM 2005 Addressing the Psychosocial and Communication Challenges posed by Radiological/Nuclear Terrorism: Key Developments since NCRP Report No 138 *Health Phys* **89** 521-530

Blakely WF, Salter WA, Prasanna PGS 2005 Early-response Biological Dosimetry – Recommended countermeasures Enhancements for Mass-Casualty Radiological Incidents for Terrorism *Health Phys* **89** 494-504

Carney JK, deFlorio F, Erickson N, McCandless R 2003 Enhancing Nuclear emergency Preparedness: Vermont's Distribution Program for Potassium Iodide *J Public Health Manag Pract* **9** 361-367

CDC Centers for Disease Control and Prevention 1998 Preventing Emerging Infectious Diseases: A Strategy for the 21st Century *US Department of Health and Human Services* (www.cdc.gov/ncidod/emergplan/plan98.pdf)

CNSC Canadian Nuclear Safety Commission 1997 Canadian Nuclear Safety Act. (http://laws.justice.gc.ca/en/N-28.3/text.html)

Coleman CN, Stone HB, Alexander GA *et al* 2003 Education and Training for Radiation Scientists: Radiation Research Program and American Society of Therapeutic Radiology and Oncology Workshop, Bethesda, Maryland, May 12-14, 2003 *Radiat Res* **160** 729-737

Danzig R, Berkowsky PB 1997 Why should we be concerned about biological warfare? *JAMA* **278** 431-432

Dodd B 2005 International Efforts in Countering Radiological Terrorism *Health Phys* **89** 556-565

Franz DRR, Jahrling PR, Friedlander AM *et al* 1997 Clinical recognition and management of patients exposed to biological warfare agents *JAMA* **278** 399-411

Goans RE, Waselenko JK 2005 Medical Management of Radiological Casualties *Health Phys* **89** 505-512

IAEA International Atomic Energy Agency 1998 Goiania, ten years later Proceedings of the International Atomic Energy Agency conference *Vienna IAEA*

Lanzilotti SS, Galanis G, Leoni N, Craig B 2002 Hawaii medical professionals assessment *Hawaii Med J* **61** 162–173

Lawson RS, Davies G, Hesslewood SR, Hinton PJ, Maxwell A 2004 Delivery and Collection of Radioactive Packages to and from UK Hospital Nuclear Medicine Departments *Nucl Med Commun* **25** 1161-1167

Lubenau JO and Strom DJ 2002 Safety and Security of Radiation Sources in the Aftermath of 11 September 2001 *Health Phys* **83** 155-164

Mettler FA 2005 Medical Resources and Requirements for Responding to Radiological Terrorism *Health Phys* **89** 488-493

Moulder JE 2004 Post-irradiation approaches to treatment of radiation injuries in the context of radiological terrorism and radiation accidents: a Review *Int J Radiat Biol* **80** 3–10

NCRP National Council on Radiation Protection and Measurements 2001 Management of Terrorist Events involving Radioactive Material **Report No 138** Bethesda USA

Neagle C 2003 Responding to the Media in Emergencies *J Nucl Med* **44** 11N-16N

Oumeish OY 2002 Nuclear Terrorism: Health and Environmental Hazards and Threats from Ionizing and Nuclear Radiation *Clinics in Dermatology* **20** 330-335

Pellmar TC, Rockwell S 2005 Priority List of Research Areas for Radiological Nuclear Threat Countermeasures *Radiat Res* **163** 115-123

Remick AL, Crapo JL, Woodruff CR 2005 US National Response Assets for Radiological Incidents *Health Physics* **89** 471-484

Richards C, Burnstein JL, Waeckerie JF, Hutson HR 1999 Emergency Physicians and biological terrorism *Ann Emerg Med 34* 183-190

Salter CA 2001 Psychological Effects of nuclear and Radiological Warfare *Military Medicine* **166** (Suppl) 17-18

Schneider AB, Becker DV, Robbins J 2002 Protecting the Thyroid from Accidental or Terrorist-Instigated 131I Releases *Thyroid* **12** 271-272

Sinzinger H, Aiginger P, Neumann I, Havlik E 2004 Radiation Alarm at an Airport after Radioiodine Therapy *Nucl Med Comm* **26** 67-68

Smith JM, Ansari A, Harper FT 2005 Hospital Management of Mass Radiological Casualties: Reassessing Exposures from Contaminated Victims of an Exploded Radiological Dispersal Device *Health Phys* **89** 513-520

Steinhausler F 2005 Chernobyl and Goiania Lessons for Responding to Radiological Terrorism *Health Phys* **89** 566-574

Stone HB, Moulder JE, Coleman CN *et al* 2004 Models for Evaluating Agents Intended for the Prophylaxis, Mitigation and Treatment of Radiation Injuries Report of an NCI Workshop, December 3–4, 2003 *Radiat Res* **162** 711–728

Tucker JB 1997 National Health and Medical Response to incidents of chemical and biological terrorism *JAMA* **278** 362-368

Turai I, Veress K, Gunalp B, Souchkevitch G 2004 Medical Response to Radiation Incidents and Radionuclear Threats *Br Med J* **328** 568-572

Vastag B 2003 Experts Advise on Potassium Iodide Use: No Protection Against Dirty Bombs *JAMA* **289** 2058

Waeckerie JF 1991 Disaster Planning and Response *N Eng J Med* **324** 815-821

Waeckerie JF, Seamans S, Whiteside M *et al* 2001 Executive Summary: Developing Objectives, Content, and Competencies for the Training of Emergency Medical Technicians, Emergency Physicians, and Emergency Nurses to Care for Casualties Resulting from Nuclear, Biological or Chemical (NBC) Incidents *Ann Emerg Med* **37** 587-601

Waller E, Wilkinson D 2006 MEDECOR – A MEDical DECORporation Strategy for First Responders NATO Human Factors and Medicine Panel - Research Task Group 099 proceedings Umea, Sweden

Wilkinson D, Prud'homme-Lalonde L, Qutob S, Segura T, Thorleifson E, Mullins D, and Lachapelle S 2006 Advancements in Biodosimetry and Radiation Injury Assessment. NATO Human Factors and Medicine Panel - Research Task Group 099 proceedings Umea, Sweden

Willis D and Coleman EA 2003 The Dirty Bomb: Management of Victims of Radiological Weapons *MEDSURG Nursing* **12** 397-401

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List of symbols/abbreviations/acronyms/initialisms

ALARA	As Low As Reasonably Achievable
CAMRT	Canadian Association of Medical Radiation Technologists
CBRN	Chemical, Biological, Radiological, Nuclear
CCPM	Canadian College of Physicists in Medicine
CME	Continuing Medical Education
CNSC	Canadian Nuclear Safety Commission
DND	Department of National Defence
HAZMAT	Hazardous Materials
PET	Positron Emission Tomography
RSO	Radiation Safety Officer
SPECT	Single Photon Emission Computed Tomography
WMD	Weapons of Mass Destruction

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Substantial effort has been placed into enhancing federal capabilities for responding to a Chemical, Biological, Radiological, or Nuclear (CBRN) terrorist attack. However, little emphasis has been placed on including the local-level medical responders in these efforts. In effecting response to a radiological incident, potentially useful resources to access are health care professionals with training in matters of ionizing radiation, namely: nuclear medicine physicians, radiologists, radiation oncologists, medical physicists, and technologists. In this report, we focus on Nuclear Medicine expertise in Canada, and place this expertise into the context of assisting with a radiological terrorist incident. Nuclear Medicine expertise, along with its supporting infrastructure has already been deployed in proportion to the distribution of the civilian population. Given the expectations that the civilian population places in these health care professionals, their immediate access to specialized equipment, and the delay between a radiological terrorist incident and the arrival of federal expert capabilities, it is likely that these health care professionals will play important roles in emergency response. These roles will likely be: identifying the nature of the incident, triage, decontamination, coordinating with First Responders, and communicating with the media. Acknowledging the potential value of these professionals in responding to a radiological terrorist incident, steps should be taken to enlist their support and integrate them into a coherent national strategy.

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